The Status of DØ: Detector and Physics

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Columbia University, New York

Annual Fermilab Users Meeting

- **The Upgraded D0 detector**
- **The Trigger System**
- **First Results**
- **Run 2 b**

DØ: An International Collaboration

644 members

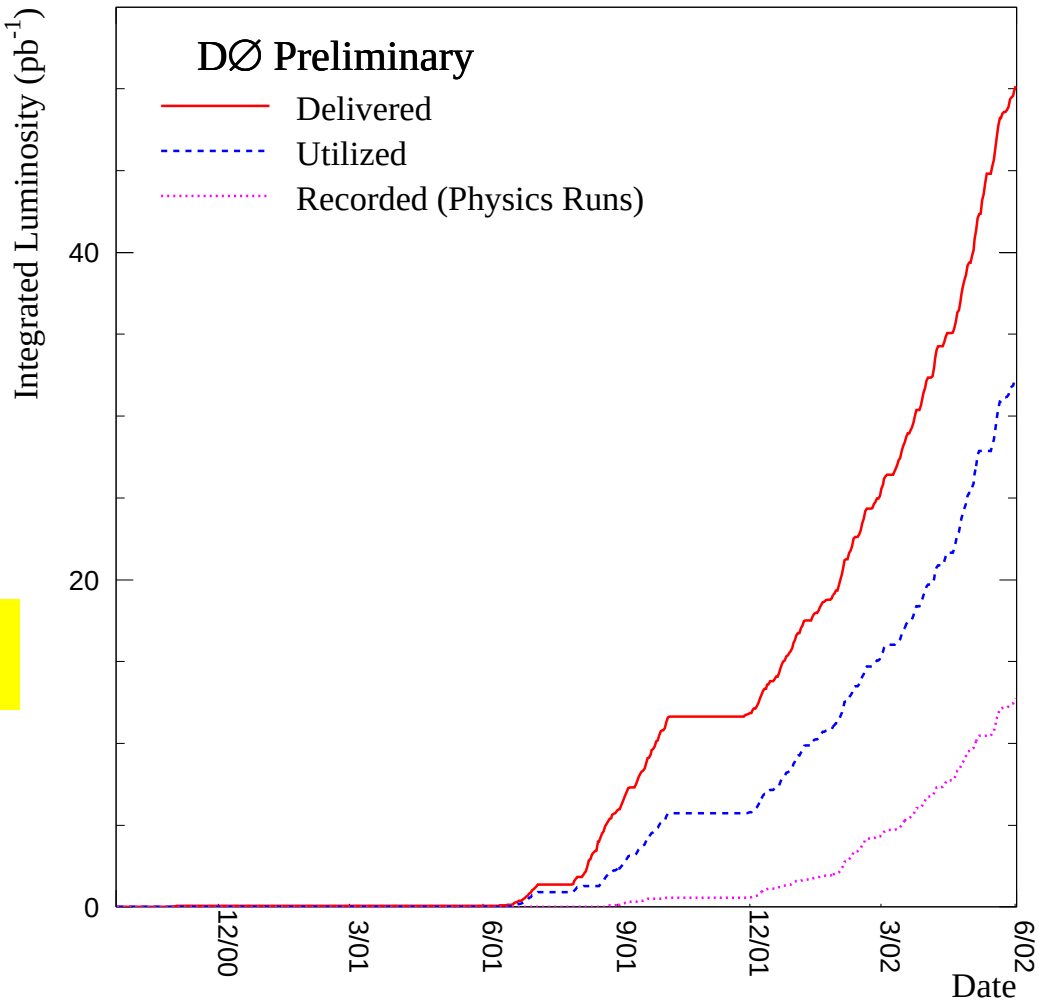
73 institutions

18 countries

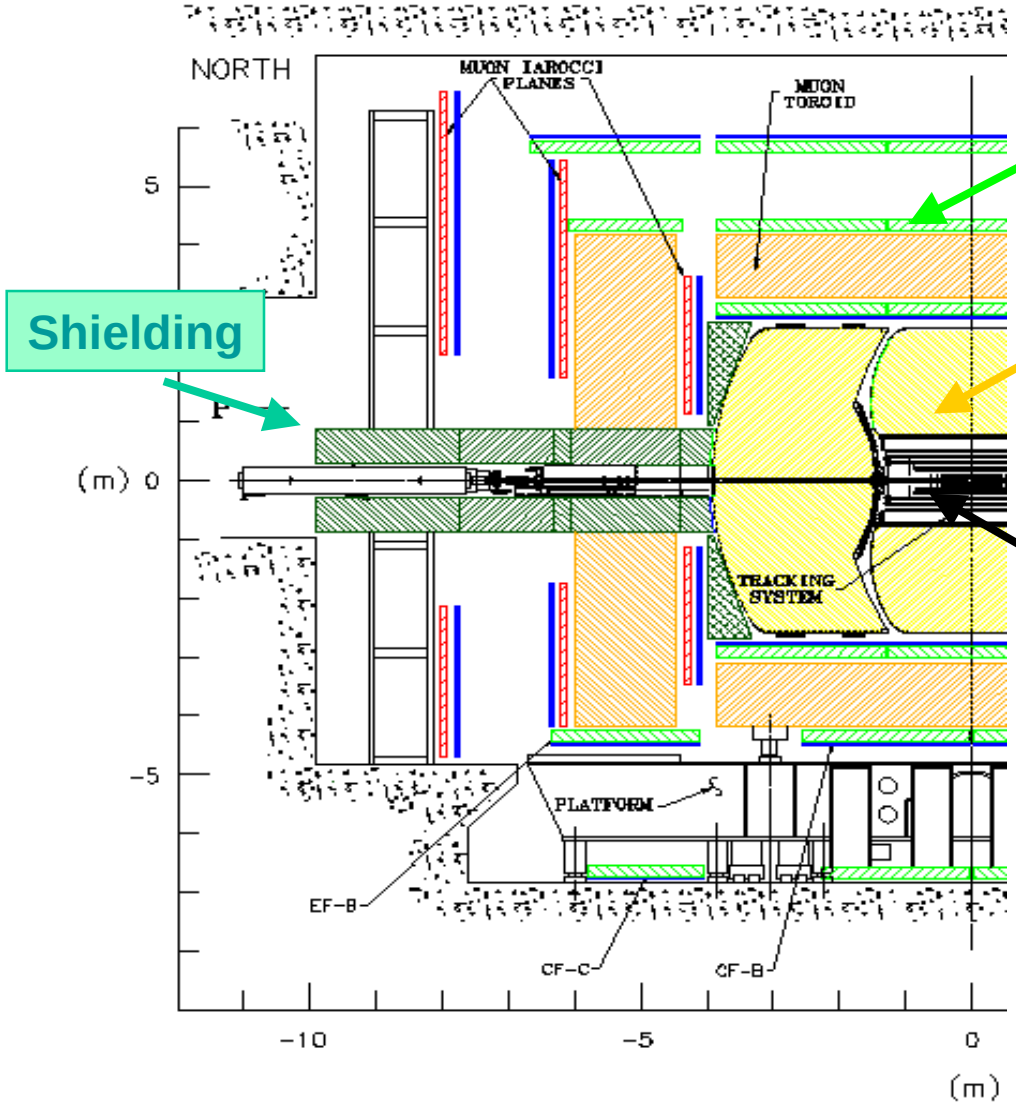
To set the stage: DØ Performance

- 38 pb^{-1} delivered in 2002
- 26 pb^{-1} utilized
- 12 pb^{-1} recorded physics
- Reconstructed within a week

84 million recorded so far



The Run 2 Detector



μ-detectors: *MDT, PDT, scintillator*

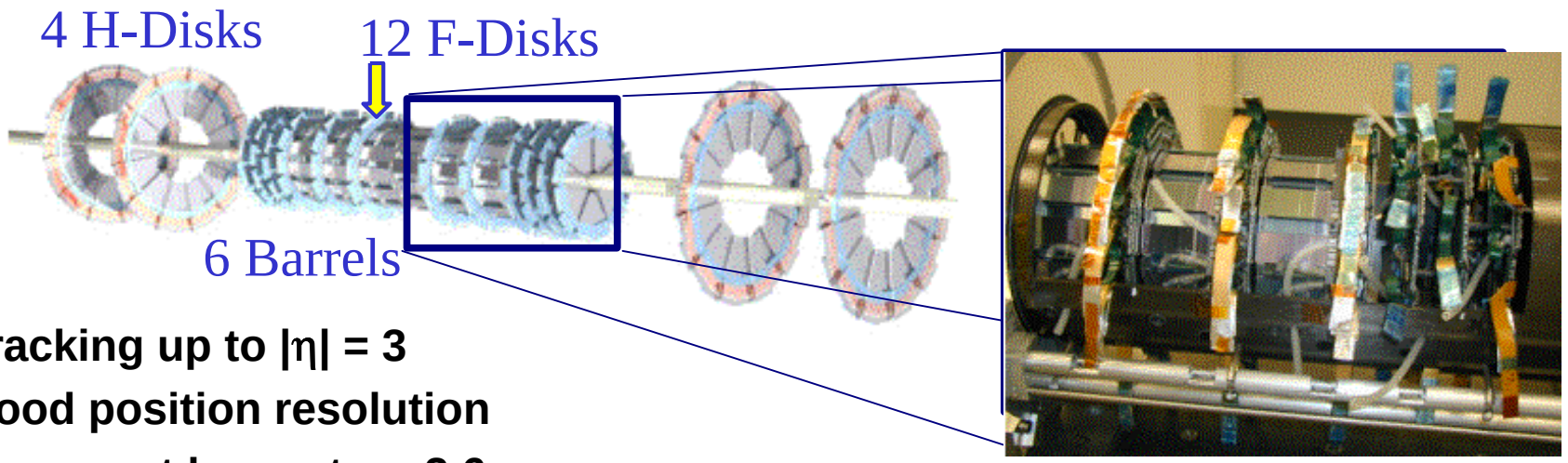
Calorimeter: *Fast Read-Out Electronics, Trigger Read-Out - preserve Run I performances in Run II environment*

Tracking Systems: *solenoid, Silicon-vertex detector, Fiber-Tracker and PreShower detectors – provide momentum measurement*

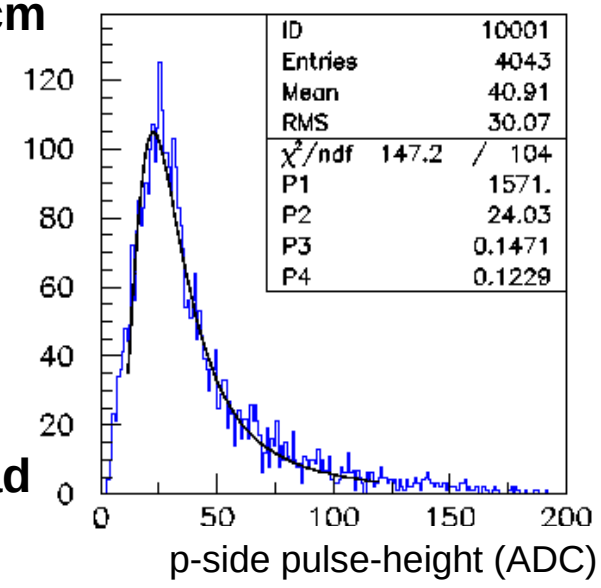
Pipelined 3 Level trigger

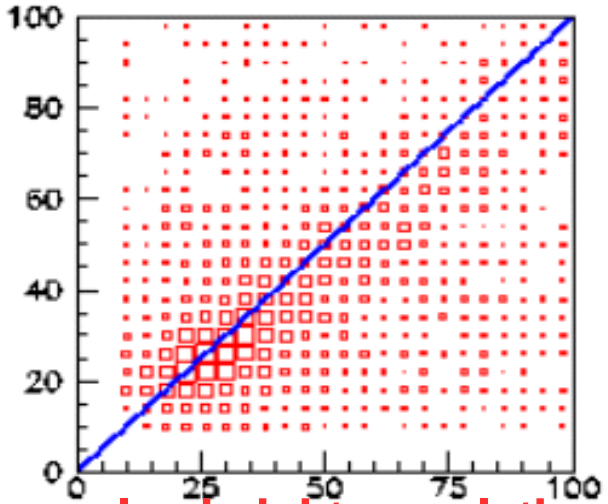
Increase DAQ capability for 132 ns bunch crossings

Silicon Microstrip Tracker (SMT)



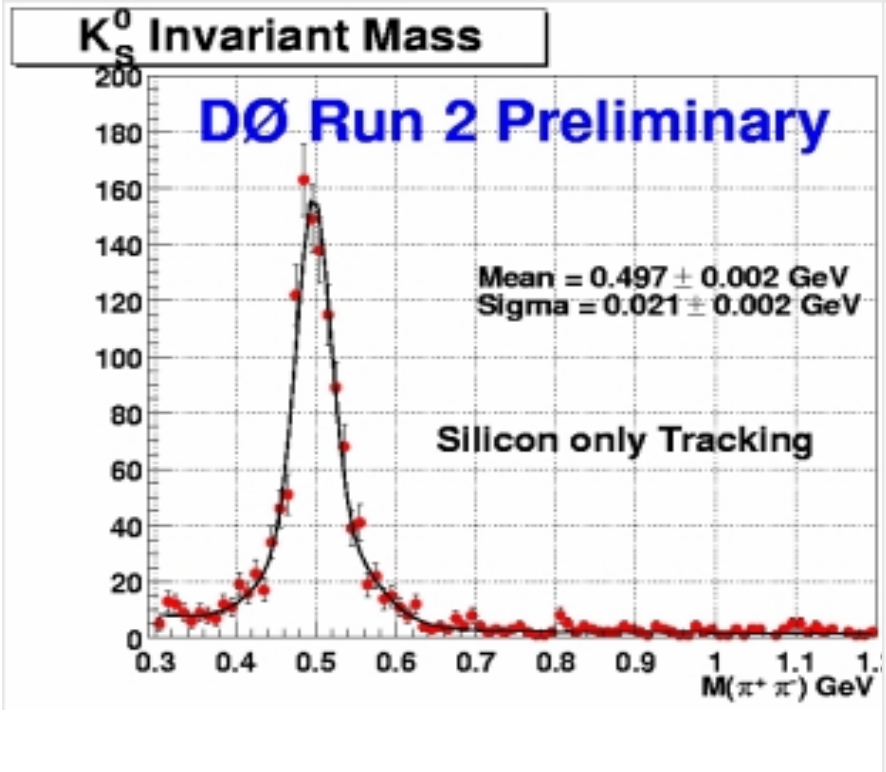
- Tracking up to |η| = 3
- Good position resolution
- Innermost layer at r = 2.6 cm
- Central region
  - 6 barrels, 4 layers SS+DS
  - 12 F-disks (DS)
- Forward region
  - 4 H-disks (SS)
- 793k channels
- Radiation hard up to 1 Mrad
- 95% channels operational

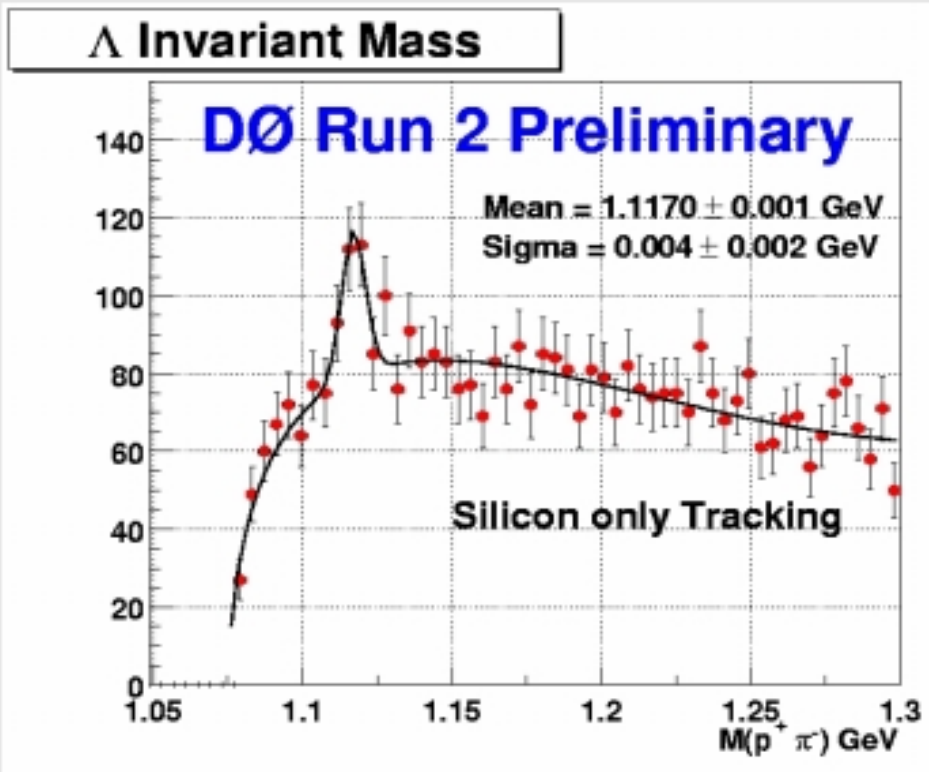




pulse-height correlation between n- and p-side

SMT Performance

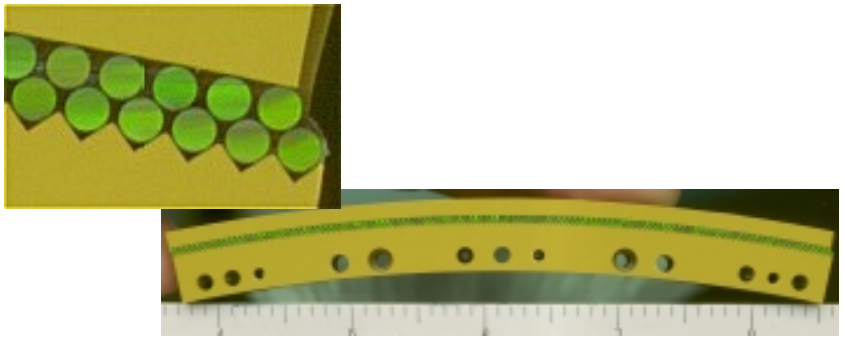


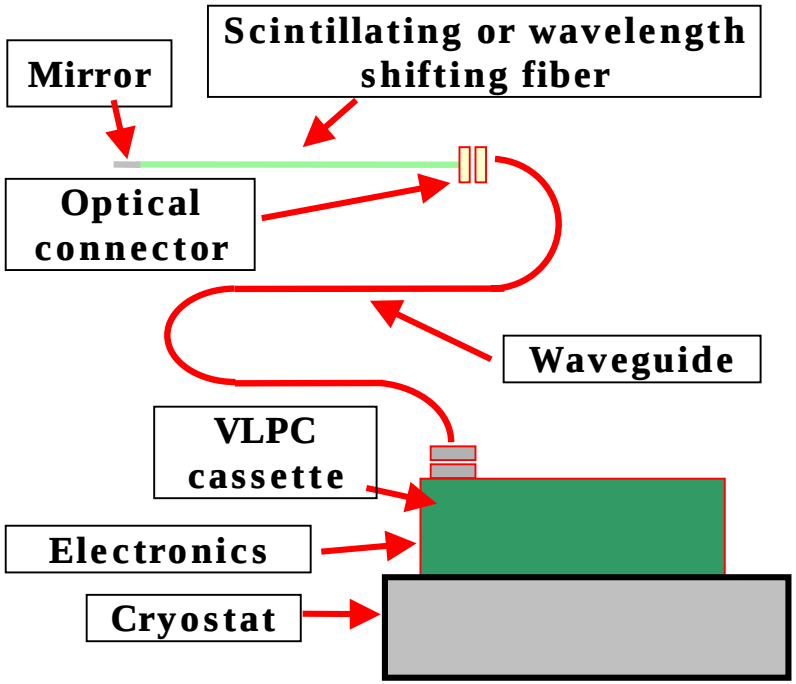


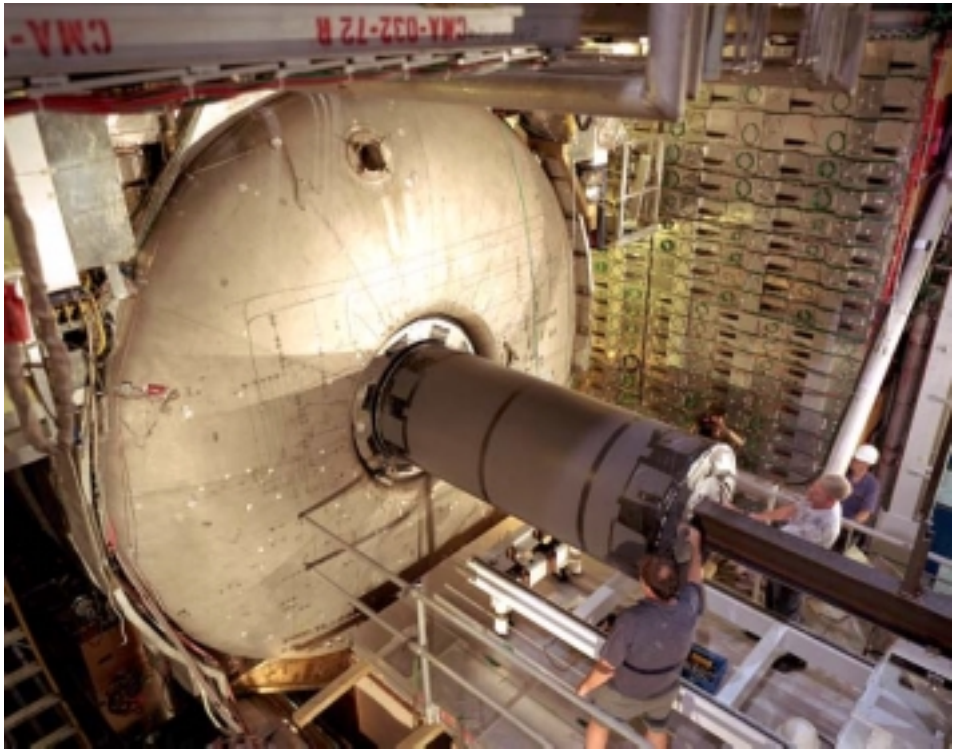
- **The SMT has been performing well**
- **Detailed Studies and Alignment under way**

The Central Fiber Tracker

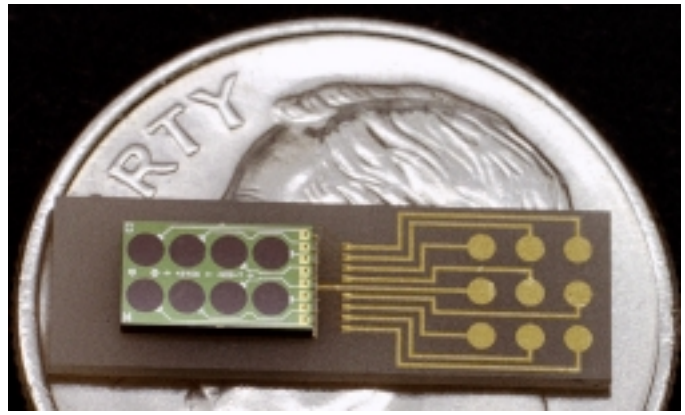
- Up to eta=1.7
- 20 cm < r < 51 cm
- 8 double layers
- CFT: 77,000 channels

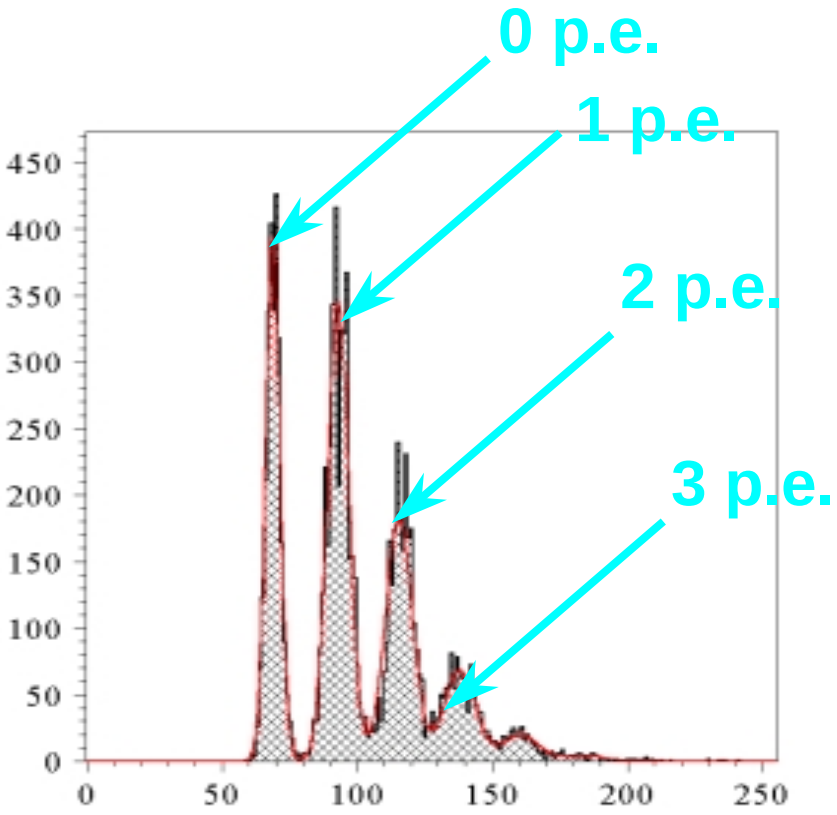






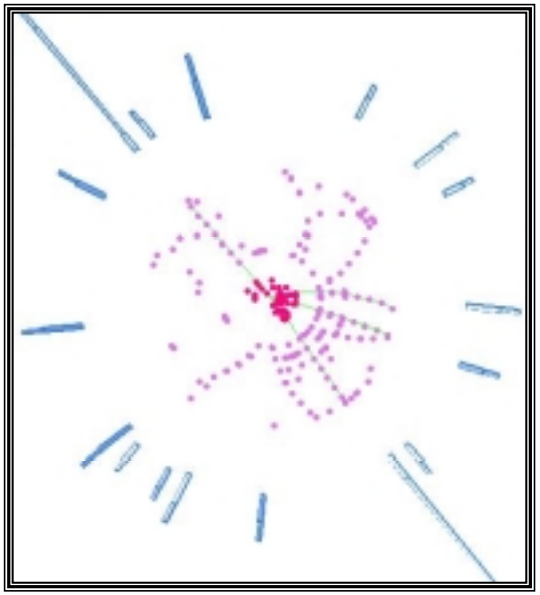
CTF Performance: VLPC



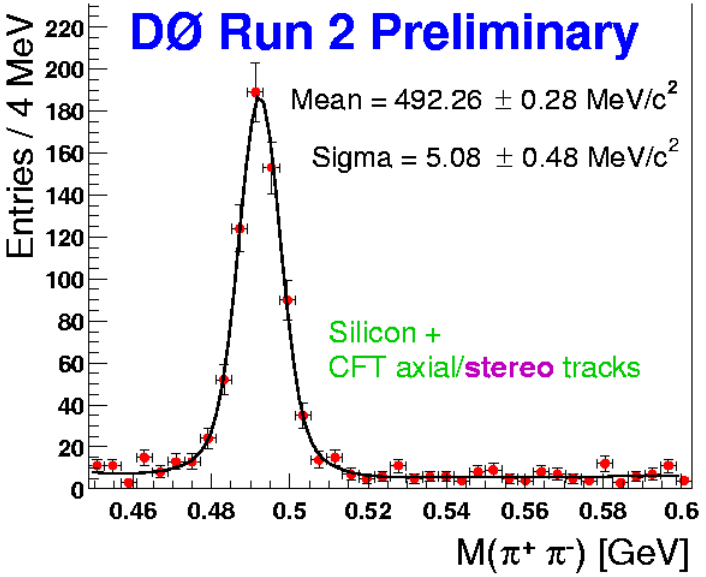


- **Visible Light Photon Counter**
  - **Solid state photon detectors**
  - **Detects single photons**
  - **~10 photons will get to VLPCs**
  - **Operate at 9 Kelvin**
  - **Work in a high rate environment**
  - **Quantum efficiency ~80%**
  - **High gain 17k to 65k electrons per converted photon**
  - **Low gain dispersion**

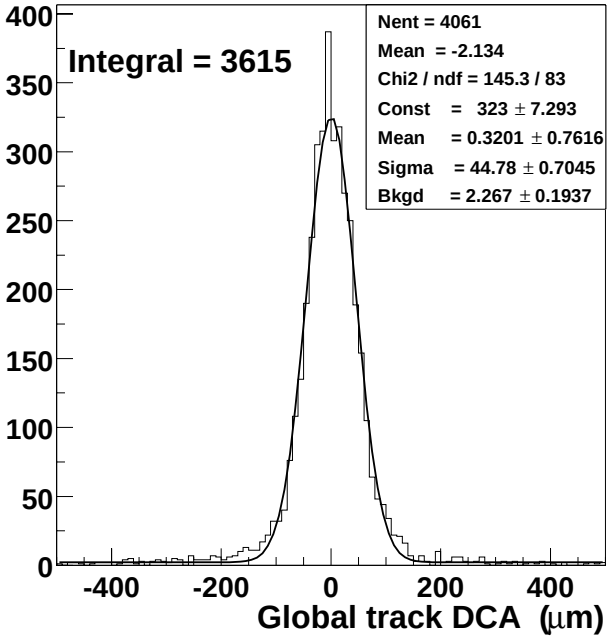
Tracking Performance



$K_S \rightarrow \pi^+\pi^-$



Impact Parameter Resolution



- **Resolution 45 μm (includes beam spot size of ~28 μm)**
- **First pass of alignment done**
- **improvements under way: expect x2 better**

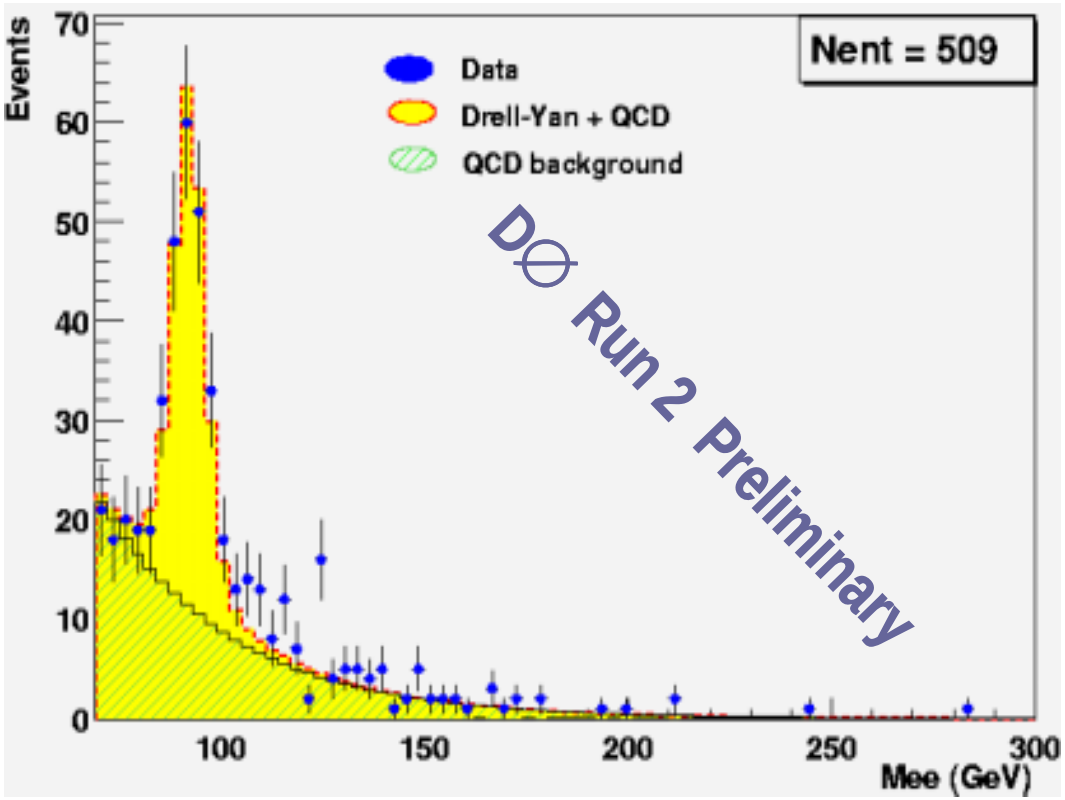
The Calorimeter

- Using Run 1 calorimeter
- Uranium-Liquid Argon
  - stable, uniform response, radiation hard, fine segmentation
- Uniform, hermetic, full coverage $|\eta| < 4.2$
- Compensating ($e/\pi \sim 1$)
- Good energy resolution
- New readout electronics to operate in Run 2 environment

Very stable running –

~50 bad channels (0.1%)

Calorimeter Performance: Z→ee



- Calorimeter performance well understood
- Working on calibration of low energy cells.

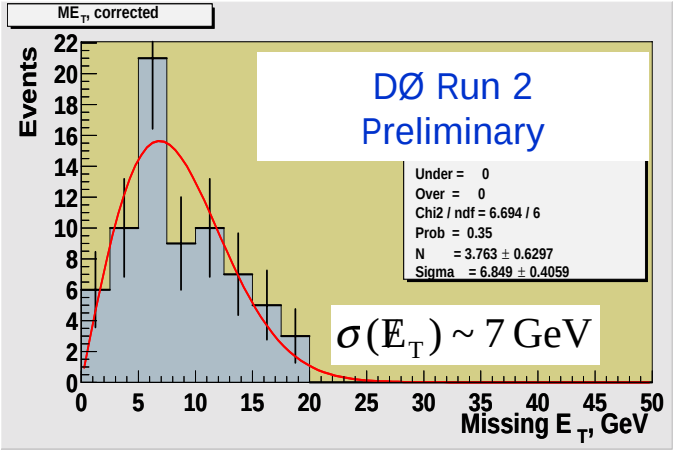
Z→ee signal (Calorimeter only)

~3 pb^{-1}

Calorimeter Performance: Missing E_T

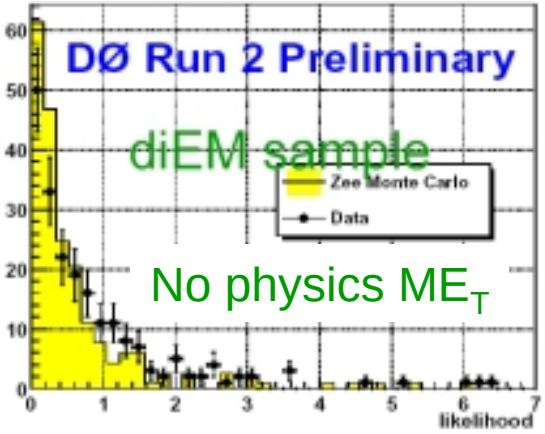
- Determine ME_T resolution from inclusive di-electron sample with at least one track match
  - Mainly Z, Drell-Yan

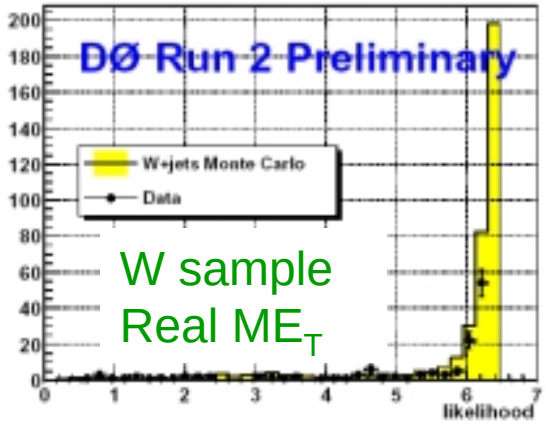
Snapshot of present performance



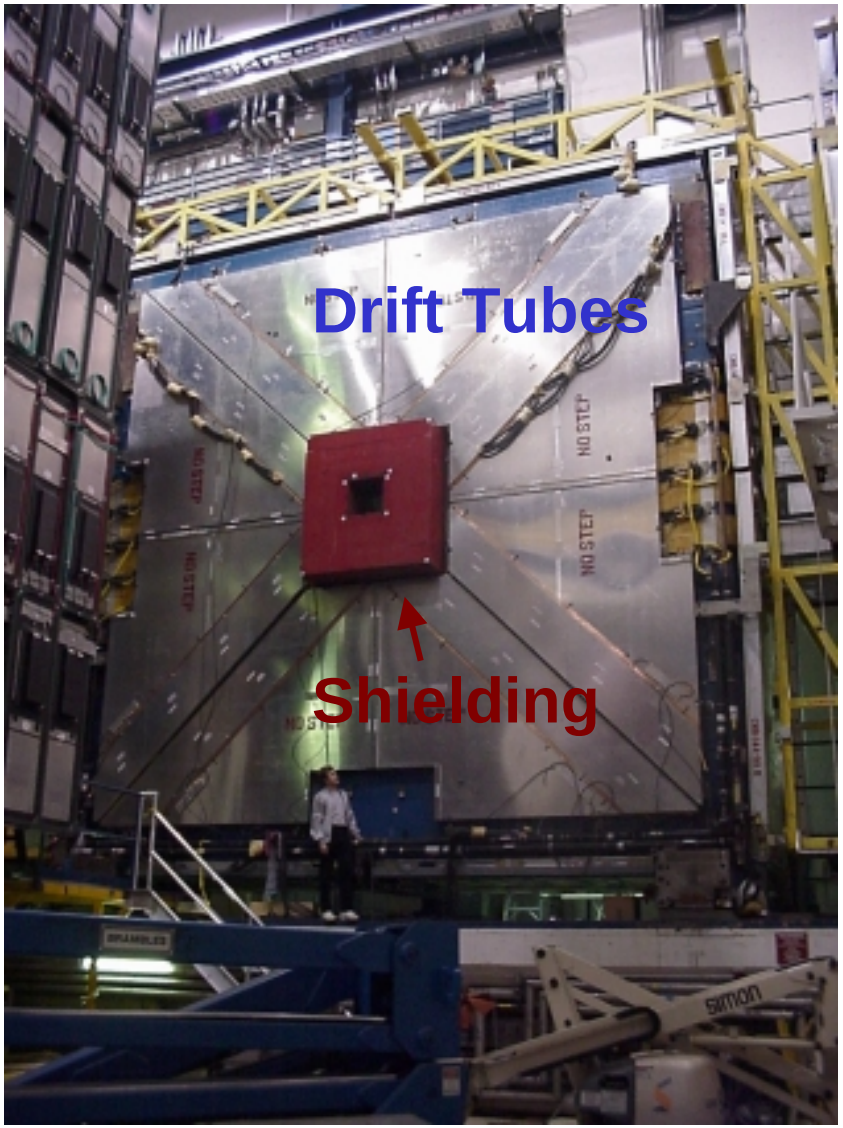
- **Use ME_T significance to take into account event topology, found vertices, and known resolutions**
  - **Low significance – no physics ME_T**
  - **high significance - ME_T not likely due to mismeasurement**

Significance is well described by Monte Carlo
→ *we understand the resolutions*





The Muon Detector

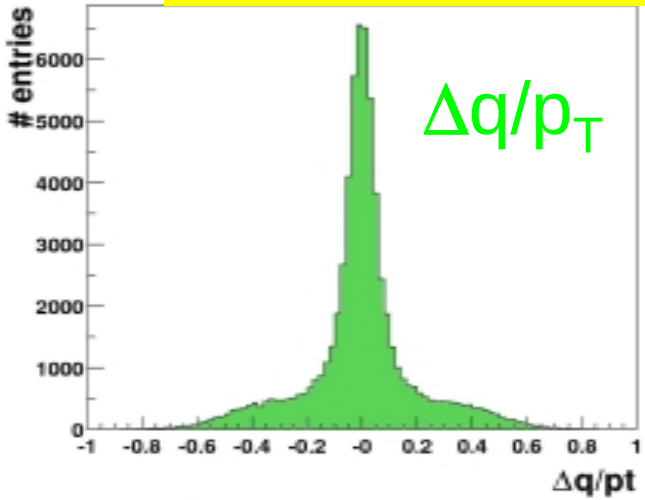


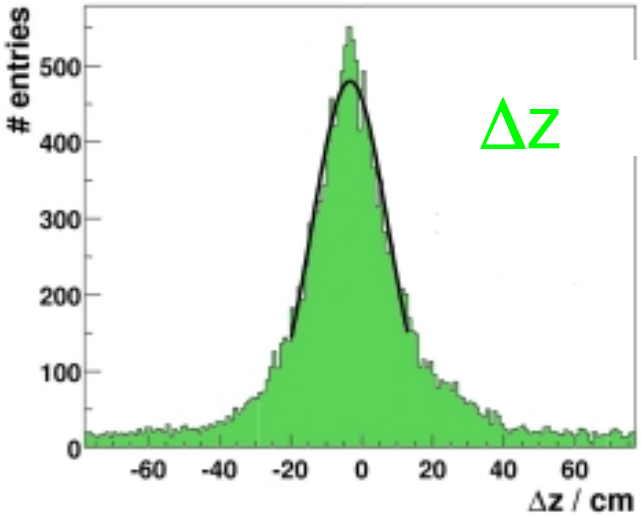
- **Two regions: Central and Forward**
- **Coverage up to $\eta=\pm 2$.**

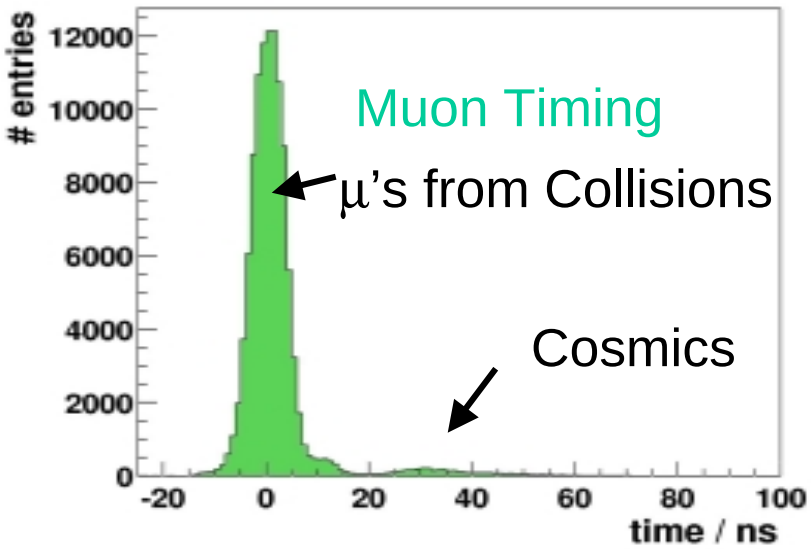
- **Three layers: one inside (*A*), two outside (*B*, *C*) the toroid magnet**
- **Consists of scintillators and drift tubes**

Muon Performance

Matching central Tracks to Muons →good momentum resolution!





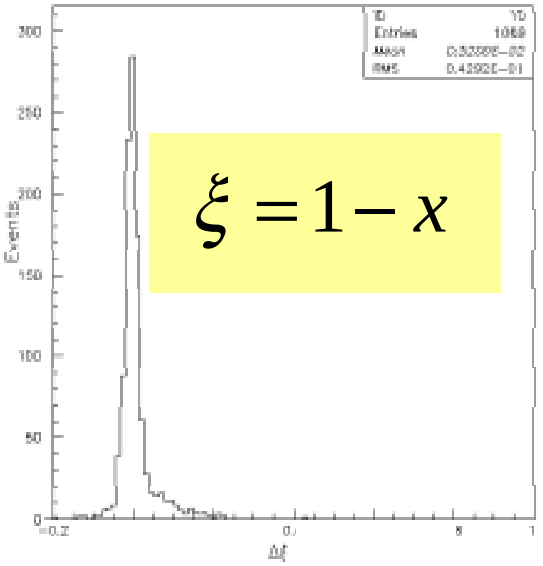


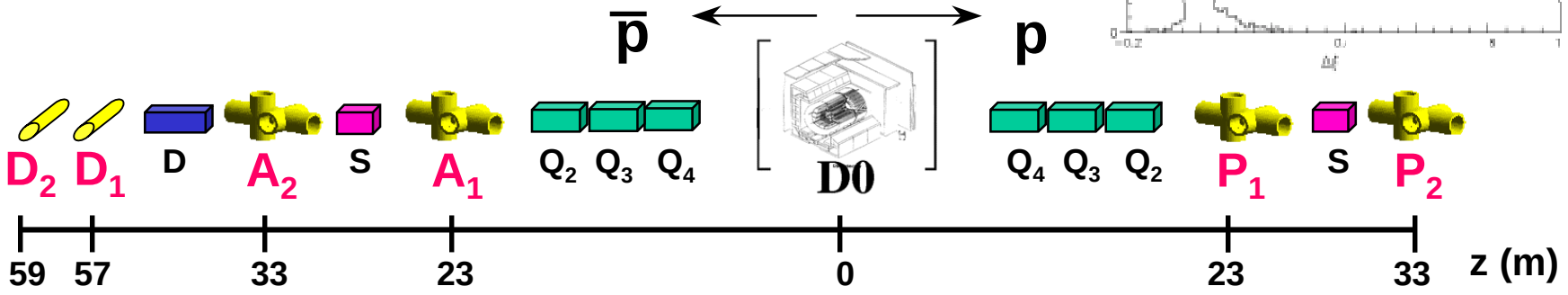
Timing cuts greatly reduce cosmic background!

The Forward Proton Detector (FPD)

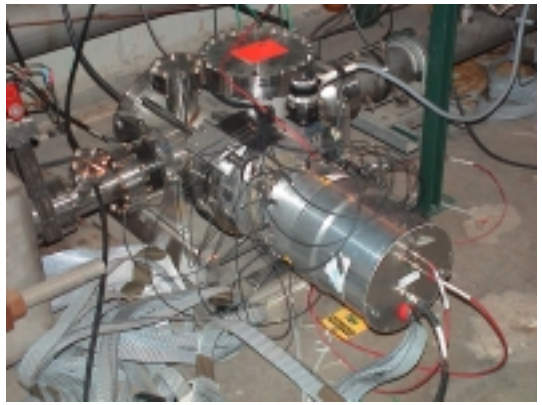
- **Diffractive Physics: Rich Physics Program**
  - **Need special detectors at very small angles : FPD**
- **FPD consists of 2 arms of**

  -Roman pots installed in 4 quadrupole and 2 dipole castles
- **From hits in scintillating fibers:**
  - **fractional energy lost by the proton and scattering angle**
  - **Trigger on elastic, diffractive, double pomeron events**





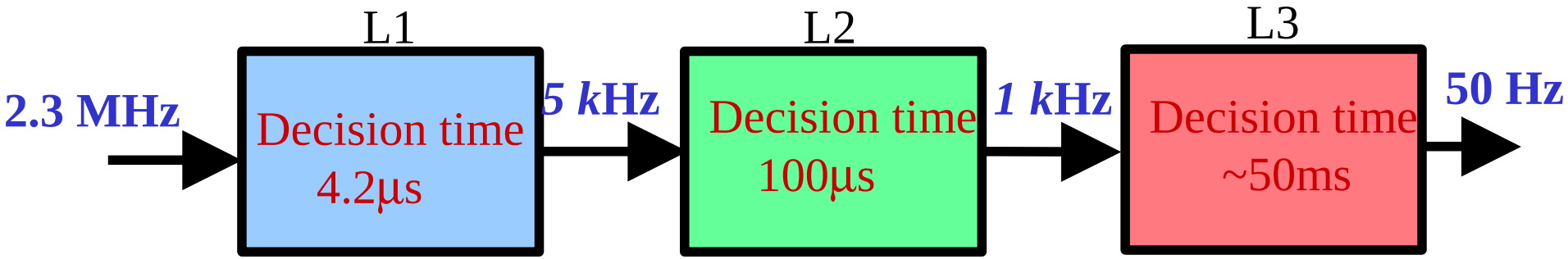
- **Routinely inserted pots during collisions**
- **Recorded > 2 M events with elastic triggers**
- **Working on integration with the rest of D0**
- **First diffractive+jet data by December**



The D0 Trigger System

But data acquisition rate is 50 Hz

⇒New 3 Level Trigger System



- Single Sub-Det's
- Towers, Tracks, E_T-miss
- Some correl's
- Not deadtimeless

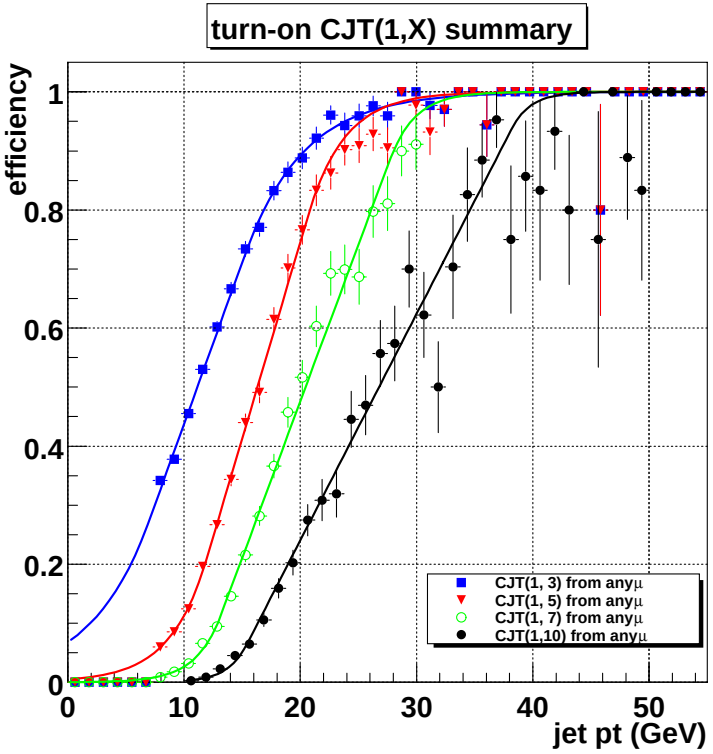
- Correlations
- Calibrated Data
- Physics Objects e,μ,j,τ,E_T-miss

- Simple Reco
- Physics Algo's

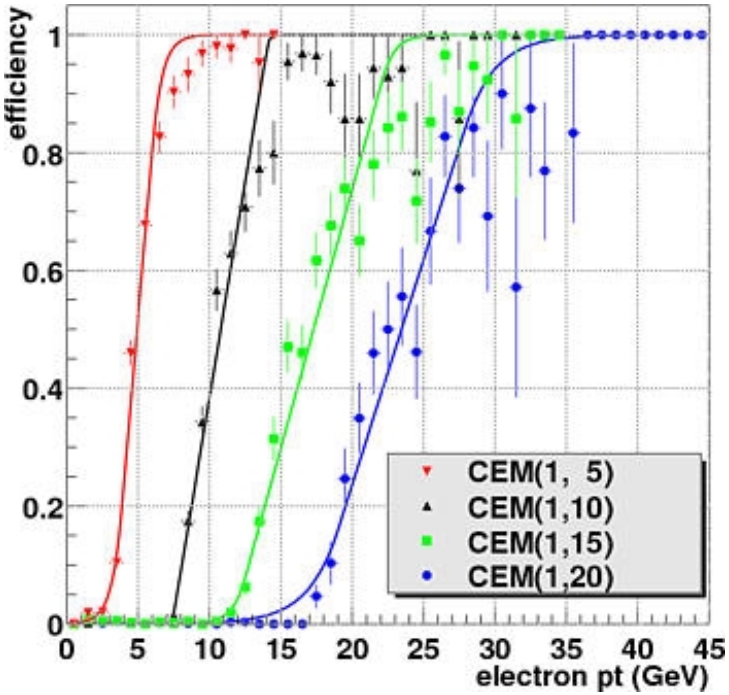
Level 1 performance

- **Trigger on EM objects, Muons, Jets**

L1 Jet turn-on



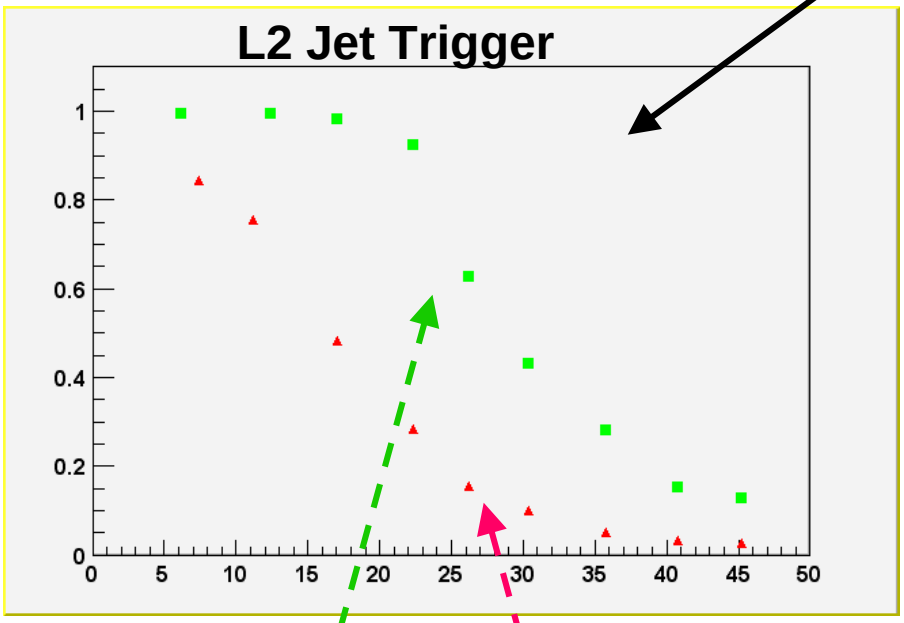
L1 EM turn-on



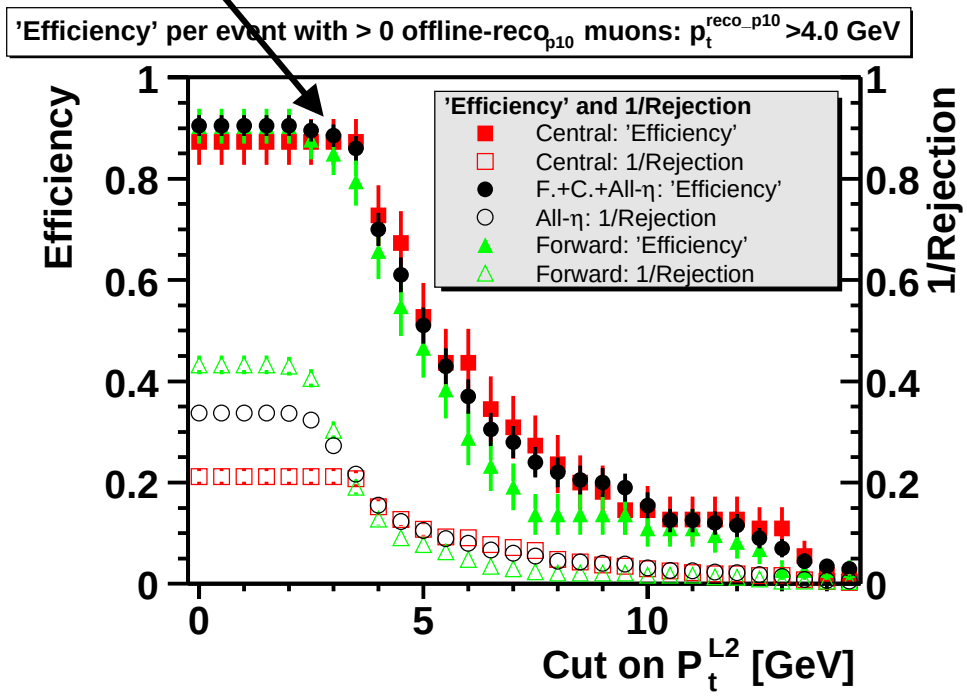
Calorimeter Trigger: All towers at |η| <1.6 are instrumented, <2.4 by the end of the week, complete coverage + MET very soon!

Level 2 performance

- **Triggering on EM objects, Jets, Muons at L2**



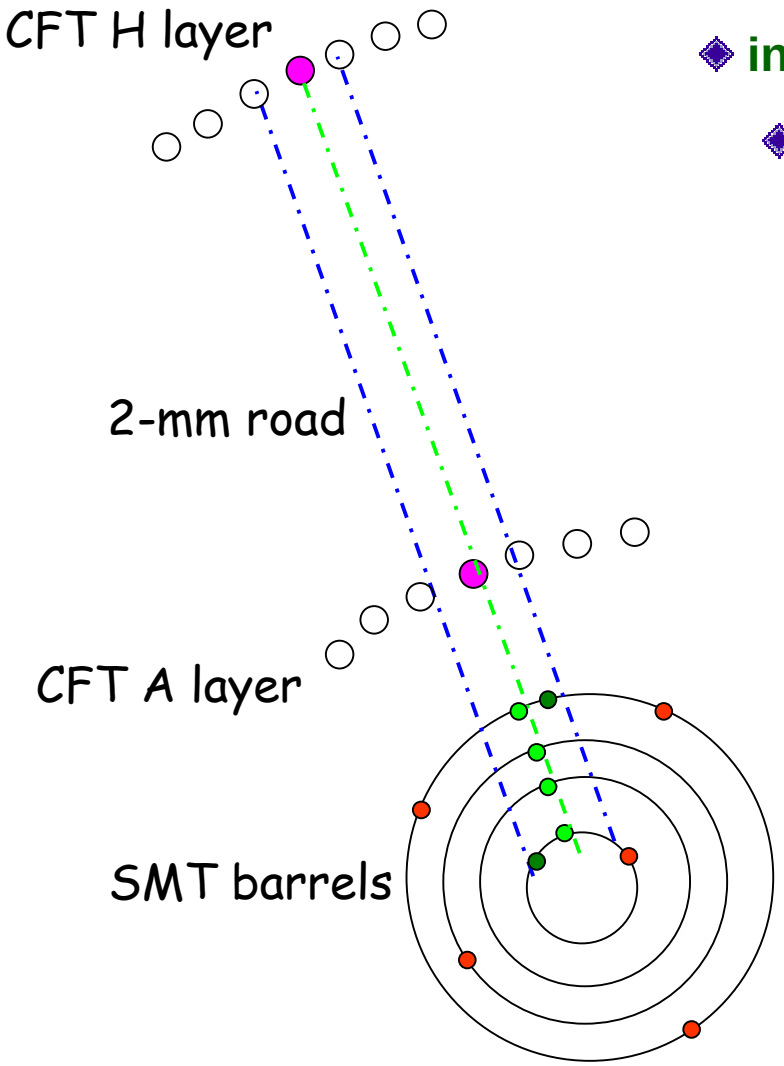
Efficiency > 1/Rejection



Offline: pT >25 GeV

- Efficiency > 1/R→Better than prescale
- Currently 5 GeV cut on single Muons:
  - limited L2 input rate: 200 Hz (2 kHz after June shutdown)

Silicon Track Trigger (STT)



Trigger on b jets containing large Impact parameter tracks:

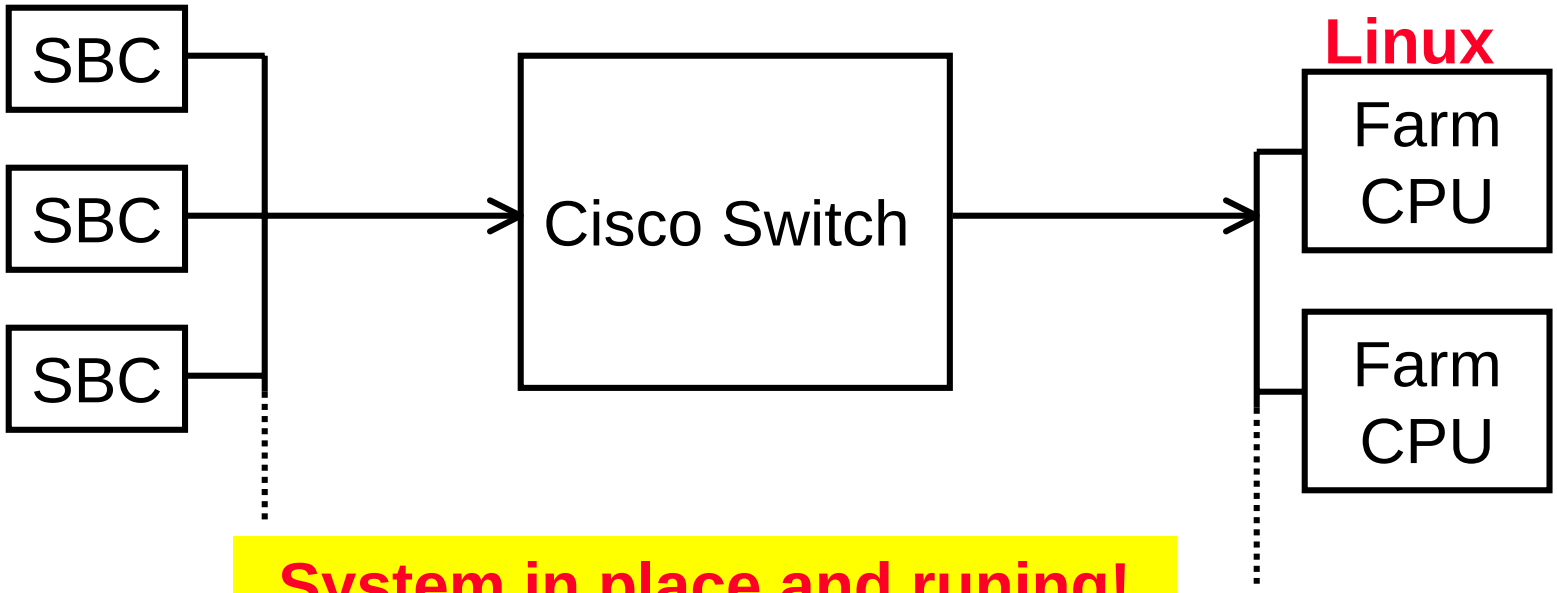
- **increase Higgs sensitivity 20% $ZH \rightarrow \nu\nu bb$**
- **Trigger on $Z \rightarrow bb$ (increase yield x6)**
  - **Cut M_t systematics in half**
- **Increase $B \rightarrow J/\psi K_S$ yield by 50%**

- **Include SMT data in track trigger (at L2)**
- **Find SMT hits in roads defined by CTT tracks**
- **Fit trajectory to L1CTT+SMT hits. Measure**
  - **pT, impact parameter, azimuth**
- **Impact parameter resolution 35 μm**

Will be online in the Fall

New L3/DAQ System

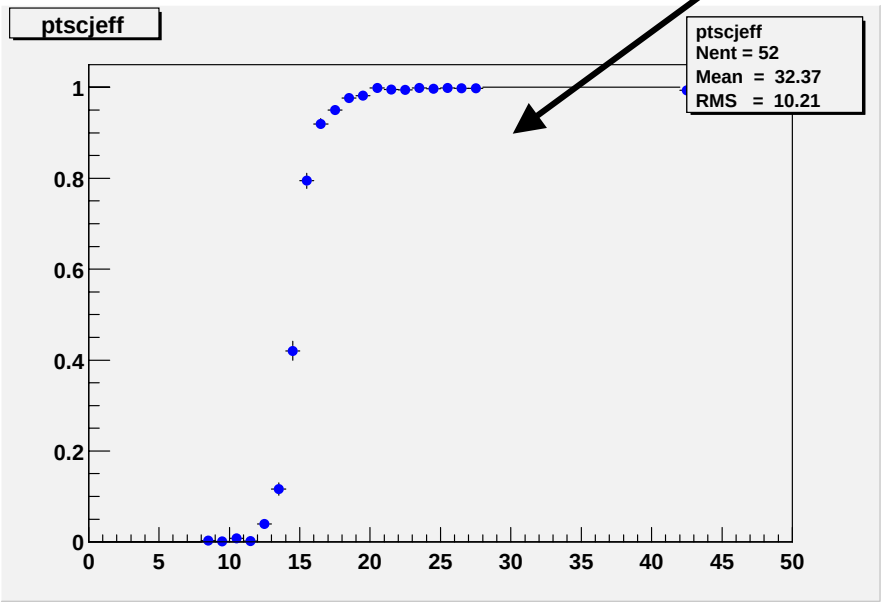
- **L3 “Commodity” DAQ**
- **Based on “off the shelf” components**
  - **Single Board Computers (SBC) to read out L3 buffers: Intel 1GHz, VME based, dual 100Mb ethernet, Linux OS**
  - **send data over fast ethernet switches**
  - **Cisco Switch sends data to Linux Farm nodes:**
  - **Event building and trigger decisions performed by Linux farm**



System in place and runing!

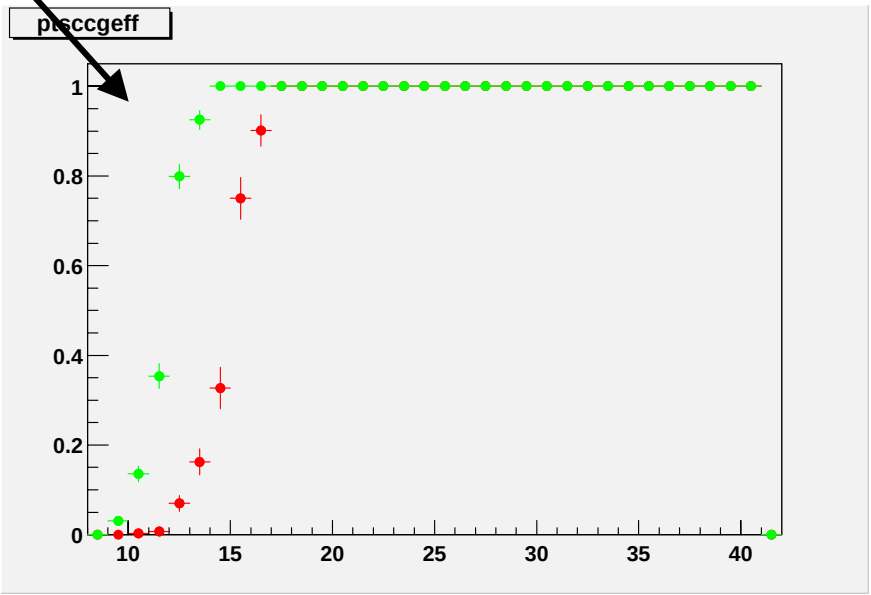
Level 3 performance

Triggering on Jets, EM objects taus, Muons



Offline Jet E_T

15 GeV Jet Trigger



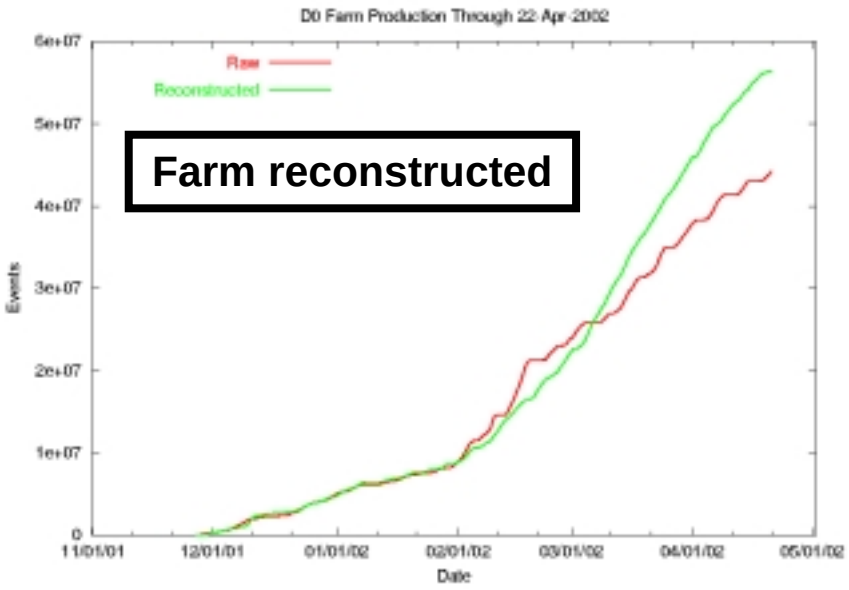
Offline EM E_T

15 GeV EM Trigger: rejection = 15 wrt Level 1 (10 GeV @ L1)

Green: 12 GeV threshold + shower shape cuts .or. the above

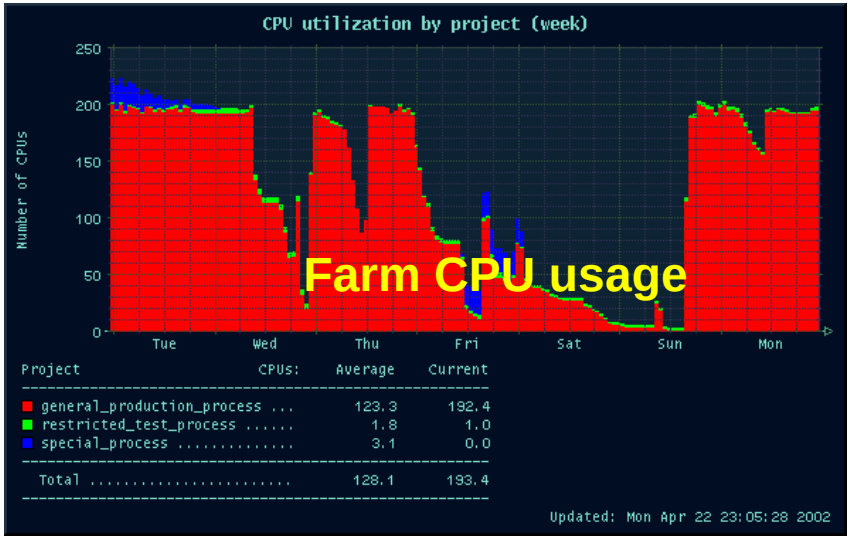
Comparing L3 to offline

Offline Reconstruction



Offline farms keeping pace with data from the detector

Reconstruction about 4 million events per day

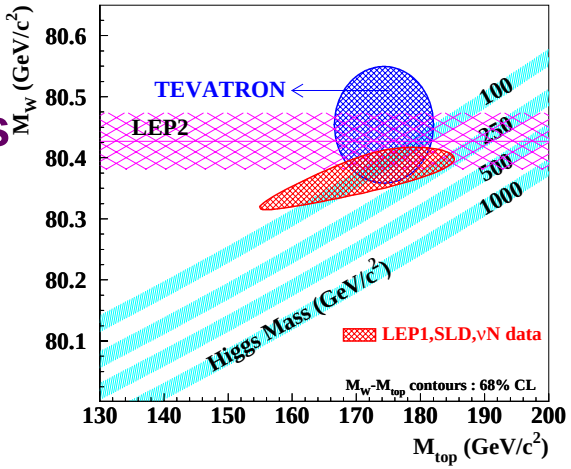


•Data Storage and Access System (SAM) has been a success!

• Remote SAM stations in place at several institutions

Physics goals for Run 2

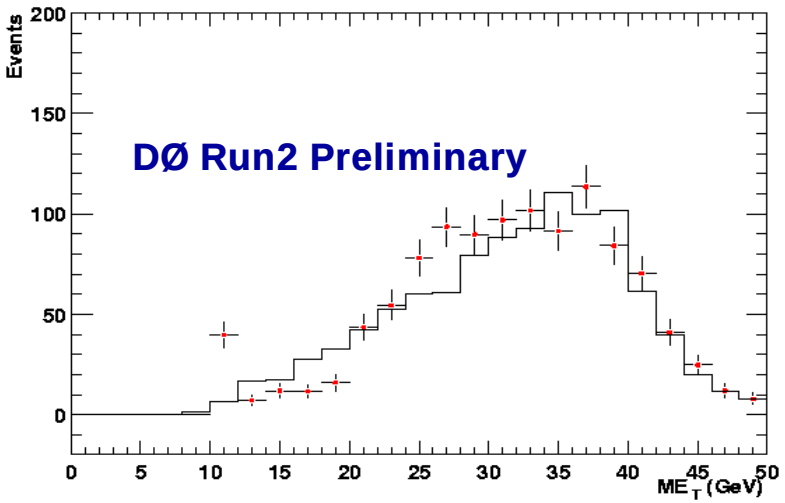
- **Explore EW Symmetry Breaking**
  - **direct searches for Higgs / new particles**
    - **Discovery potential: SUSY,…**
    - **or exclusion of large areas of phase space**
  - **precision measurements of EW param's**
    - **W mass to 30 MeV / Width to ~12 MeV**
    - ***O*(2k) Top events: Top mass to 2 GeV**
    - **Test of SM – window for New Phenomena**
    - **sensitivity to H.O. effects from Higgs/New Phys**
- **QCD studies: High E_T jets, Dijets, Diffraction,…**
- **B Physics: b production, sin 2β, B_S mixing**



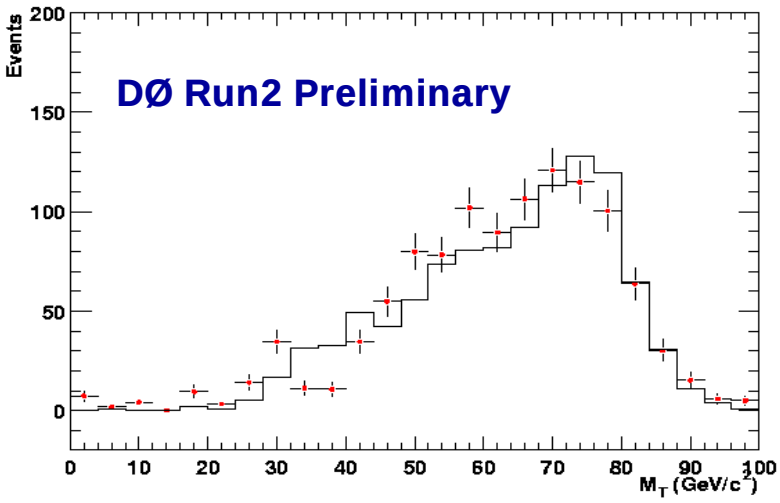
- **Combining results with CDF: Tevatron averaging WG's in place and ready for business**

W→eν

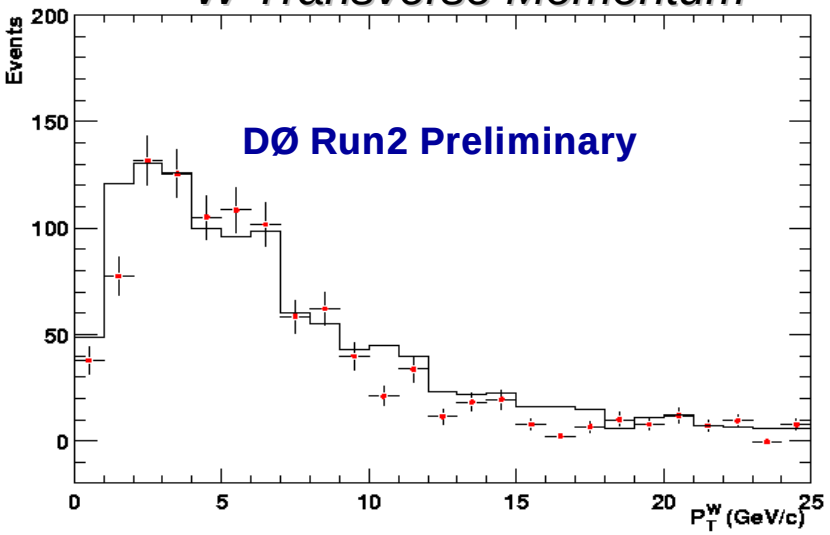
Missing Transverse Energy



Transverse Mass



W Transverse Momentum



- **All distributions subtracted for QCD background**
- **Agreement with MC!**

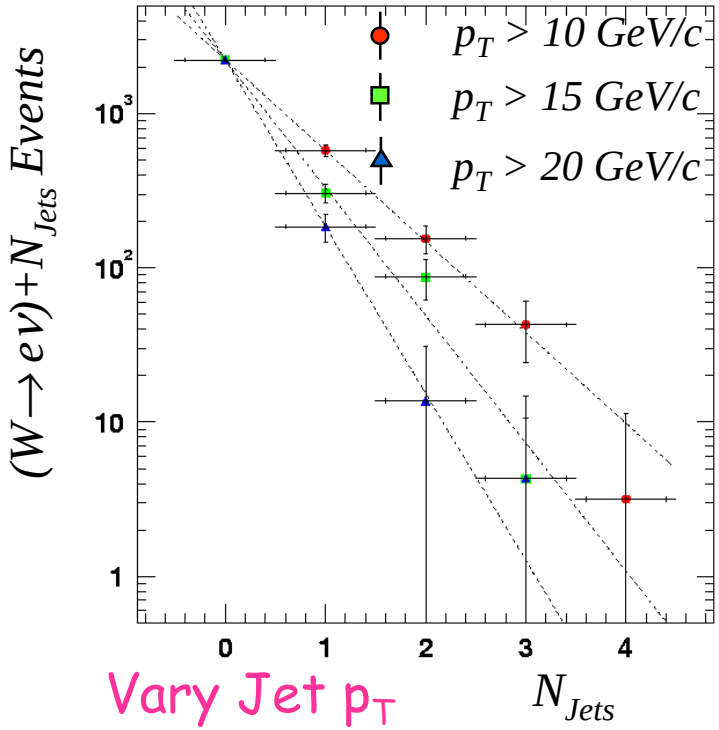
$M_T\,(GeV/c^2)$

Studies of W+Jet distributions

Distributions are background subtracted

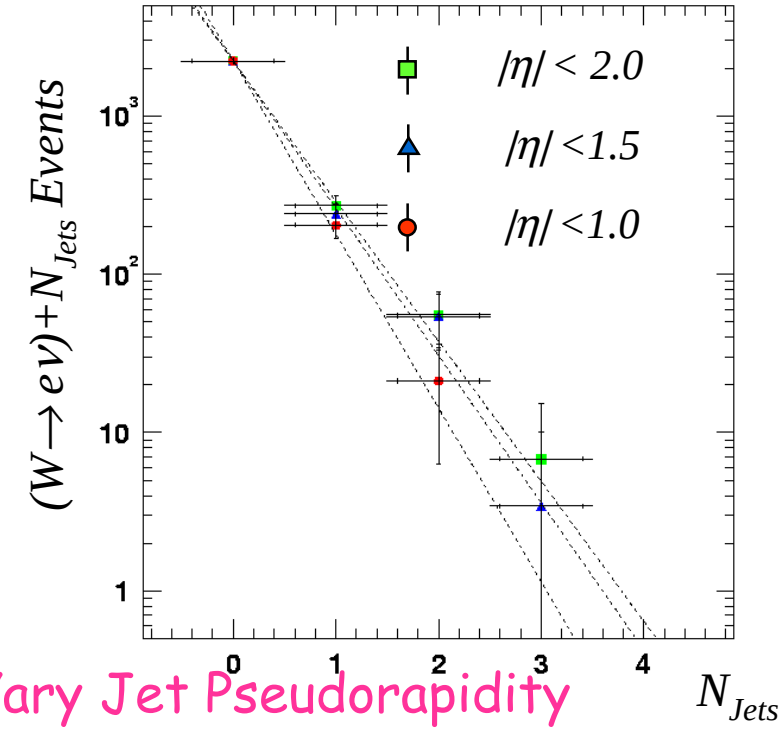
EM objects matched to tracks, EM E_T>20GeV, E_T^{miss}>20GeV

DØ Run2 Preliminary



Vary Jet p_T

DØ Run2 Preliminary



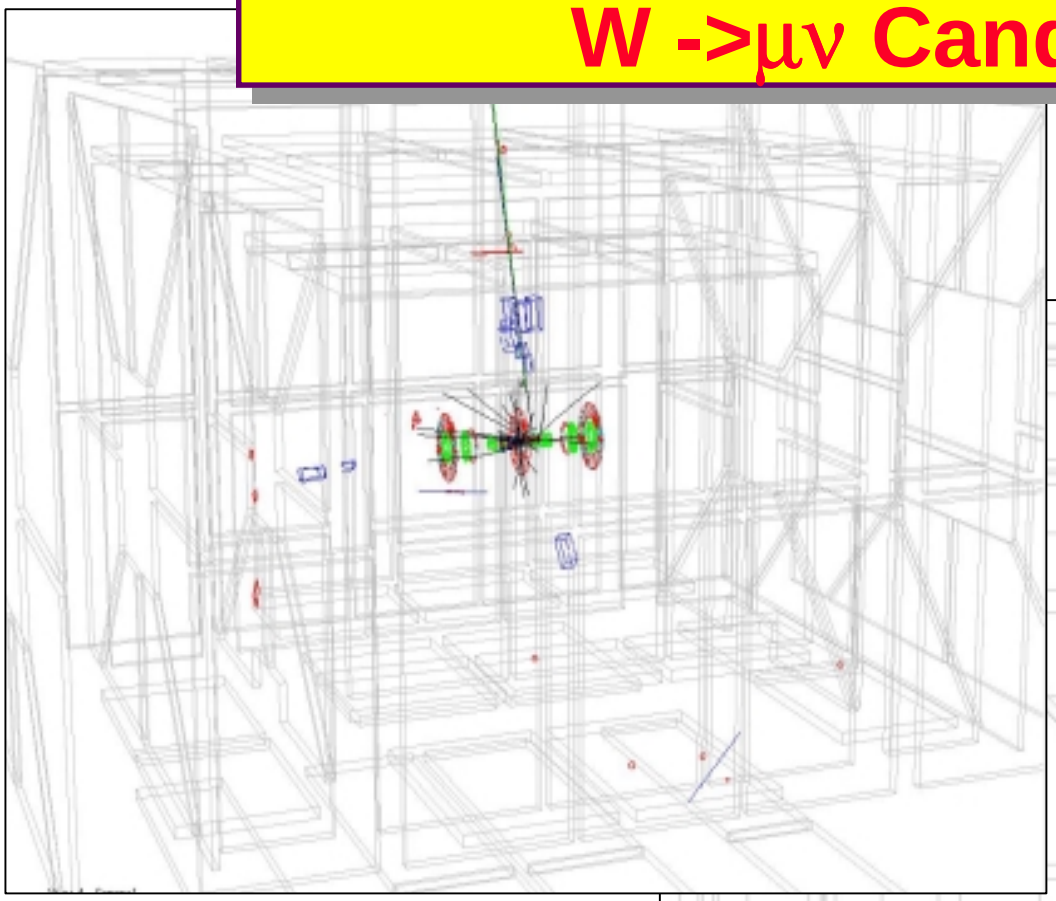
Vary Jet Pseudorapidity

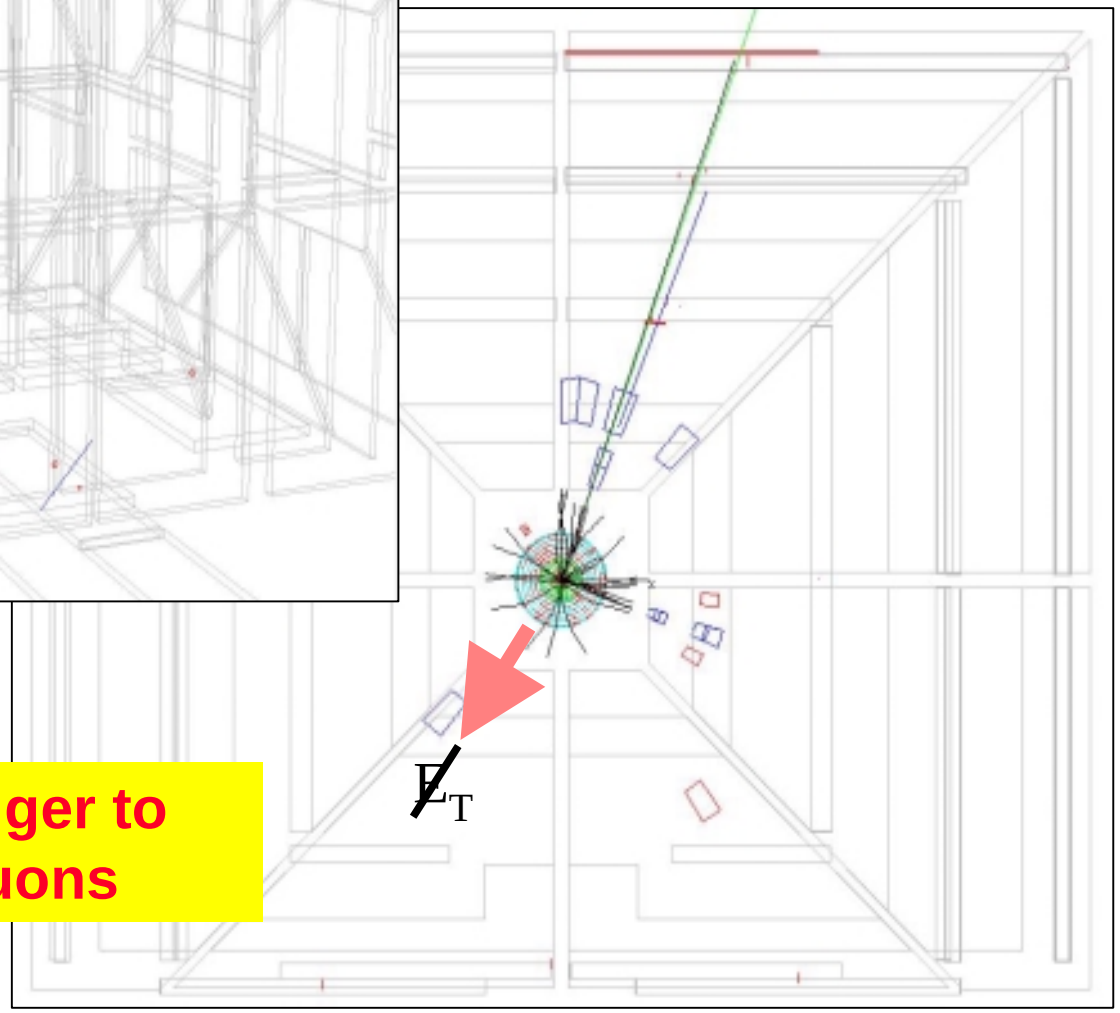
- Berends scaling.
- W+jets important background to top!

~6 pb^{-1}

W ->μν Candidate

Central track matched to muon
Transverse Mass = 78 GeV

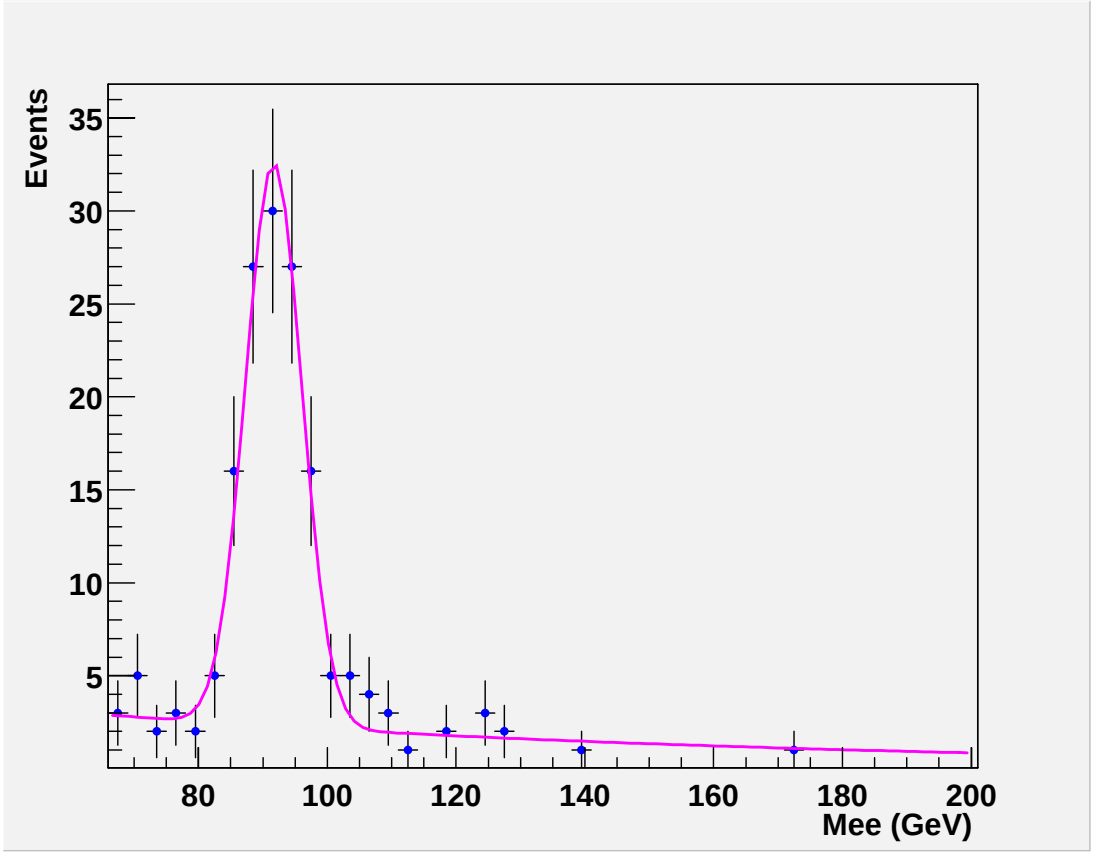




Waiting for Track Trigger to trigger on Single Muons

Z→ee

DØ Run 2 Preliminary

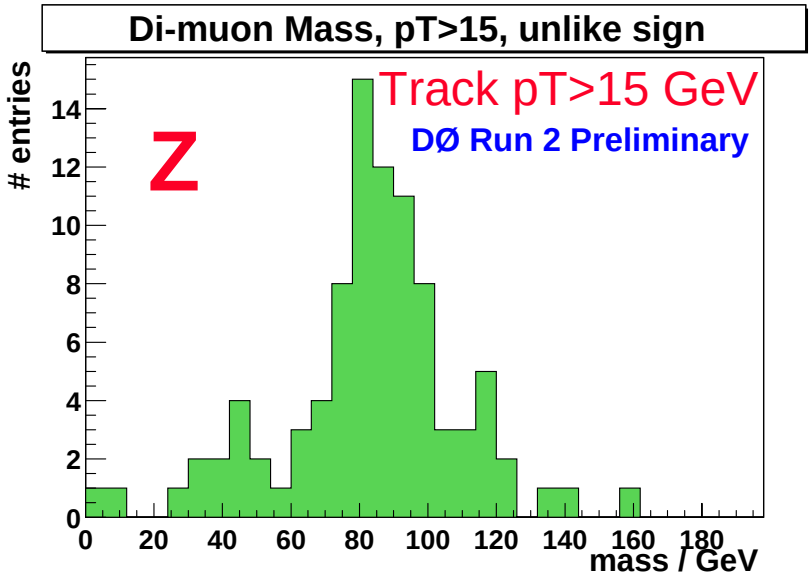


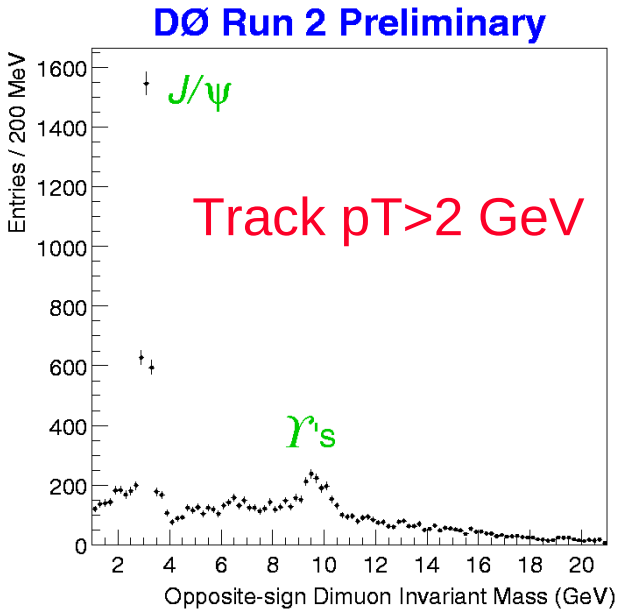
One Calorimeter Clusters matched to Central Track

Low backgrounds!

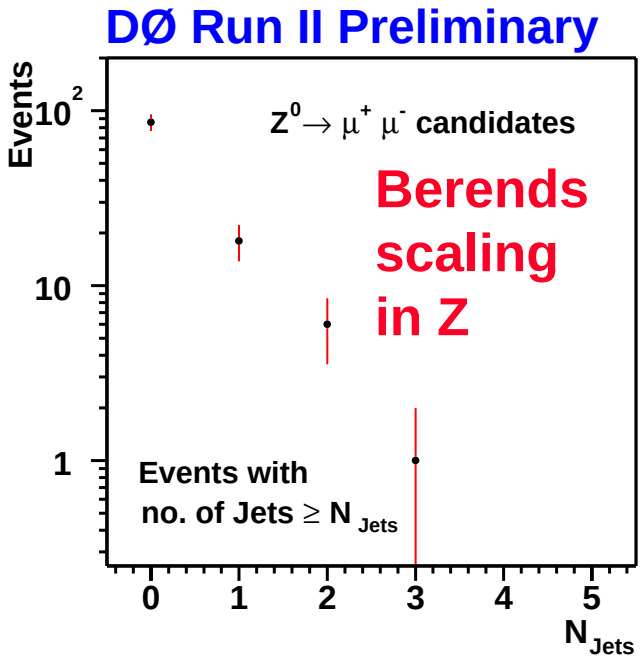
~3 pb^{-1}

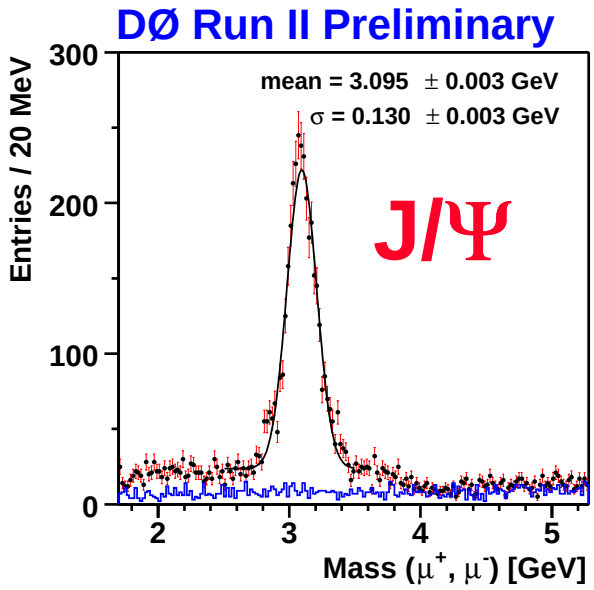
Z, J/Ψ and ϒ → μ μ



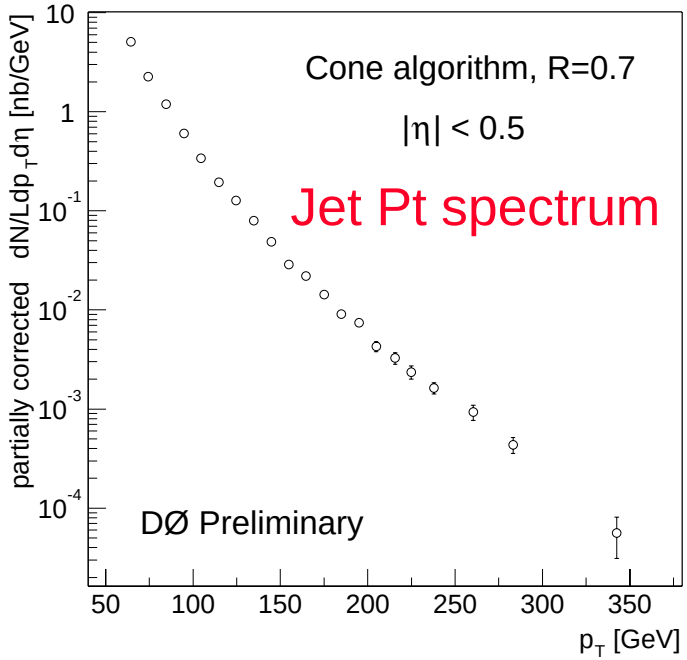


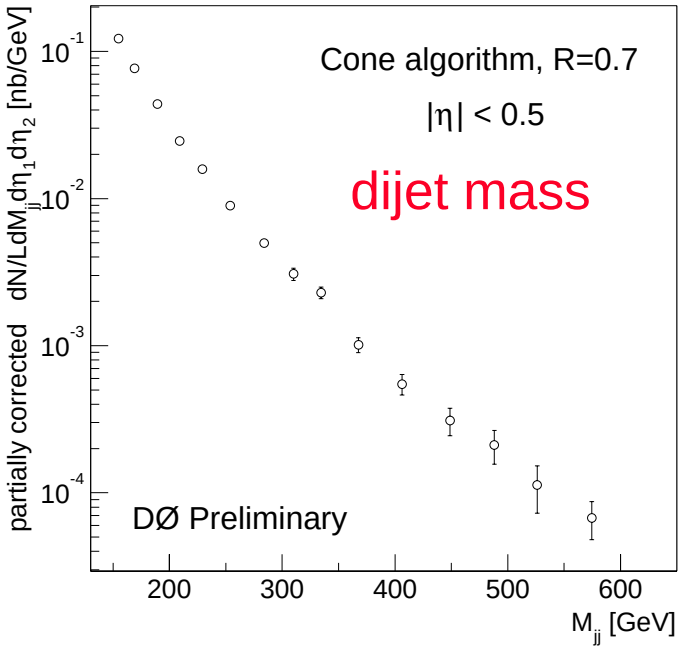
Unlike Charges





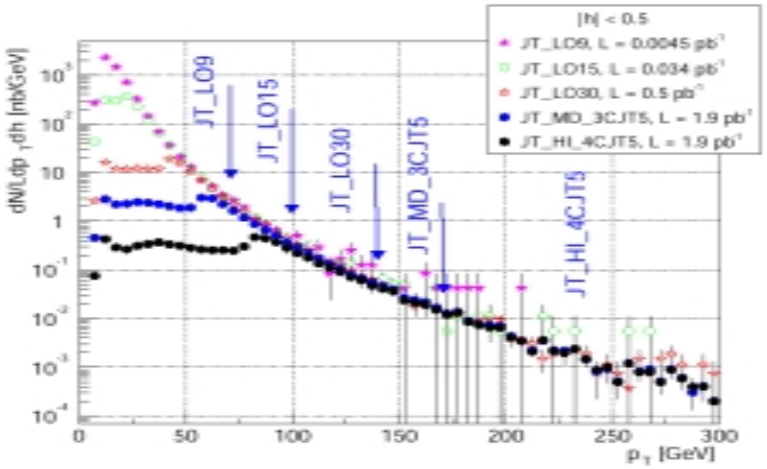
Understanding jets: On the way towards QCD





Many different triggers used!

- **Preliminary Jet Energy Scale from Jet+γ data**
- **∫Ldt ~2 pb^{-1}**



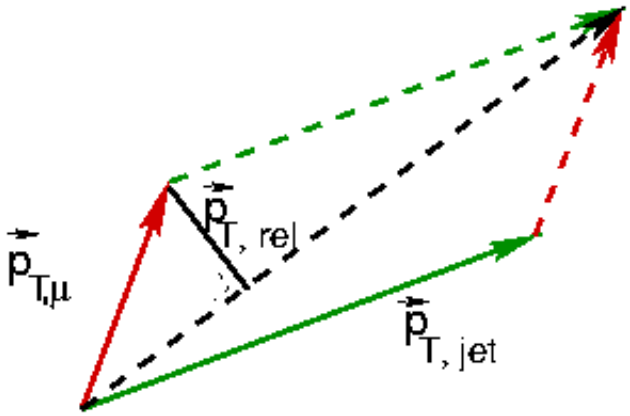
b tagging with Muons

b Tagging:

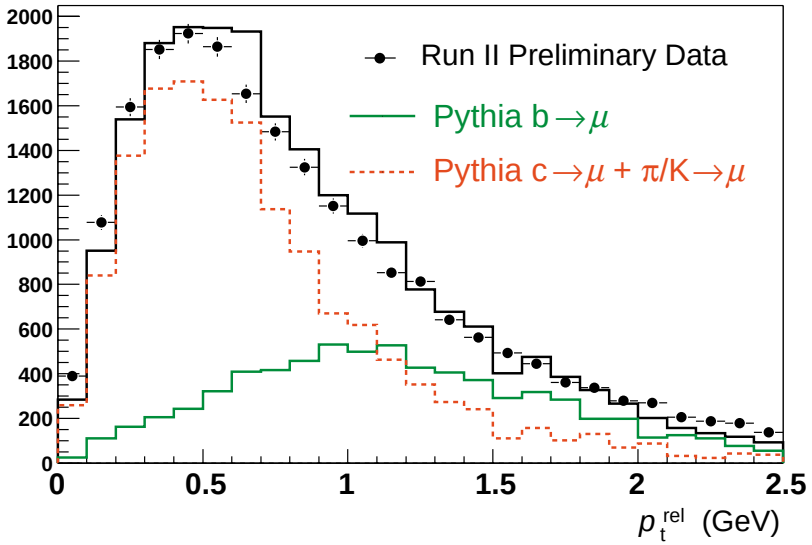
- **Top, Higgs, …**
- **B Physics**

- Tagging b→WX→μνX

Relative P_T of muon wrt jet axis: p_T^{rel}



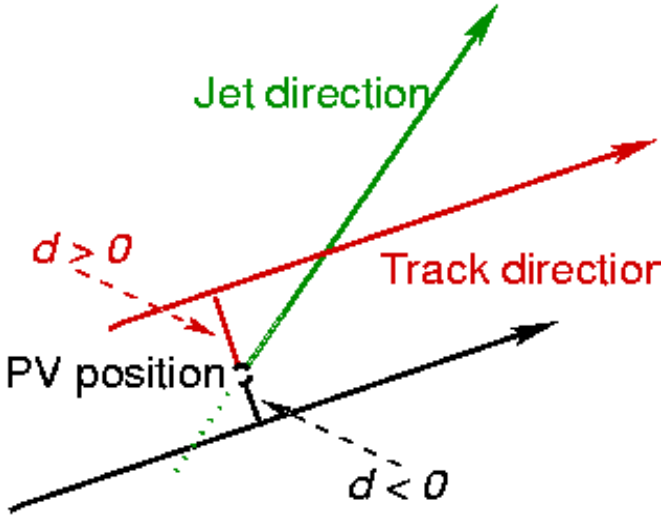
DØ Run 2 Preliminary

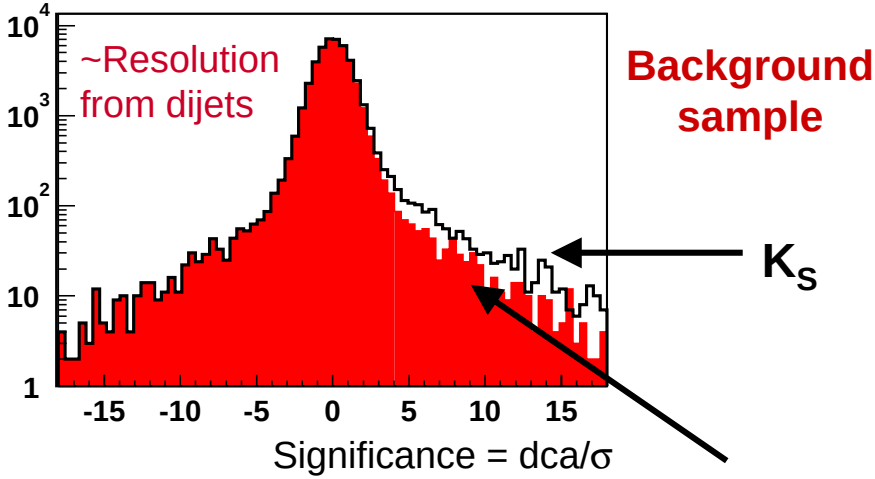


Fitting $\mathbf{p_T^{rel}}$ distribution to a mixture of b→μ and background templates to determine b content

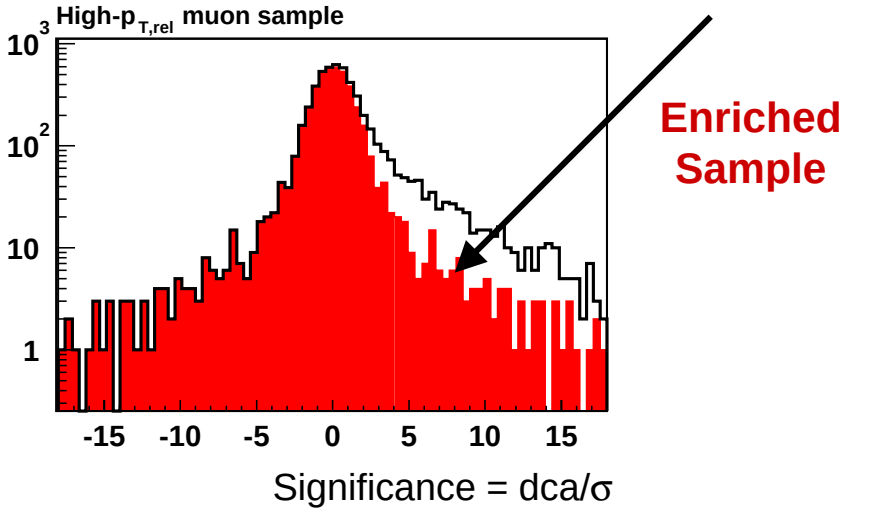
Impact Parameter b tagging

- Relies on long lifetime of B hadrons ($c\tau \sim 1.5$ ps)
- Does not rely on presence of reconstructed secondary vertices





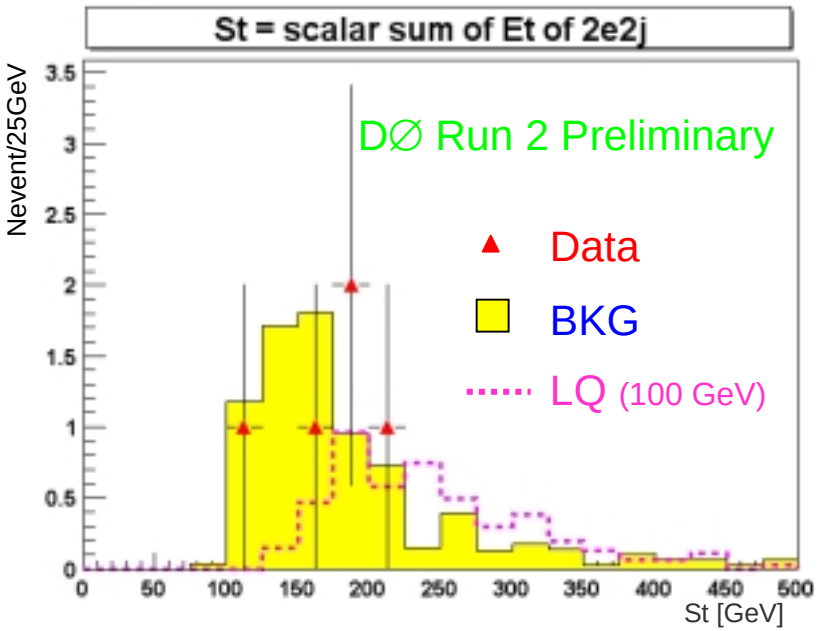
DØ Run 2 Preliminary

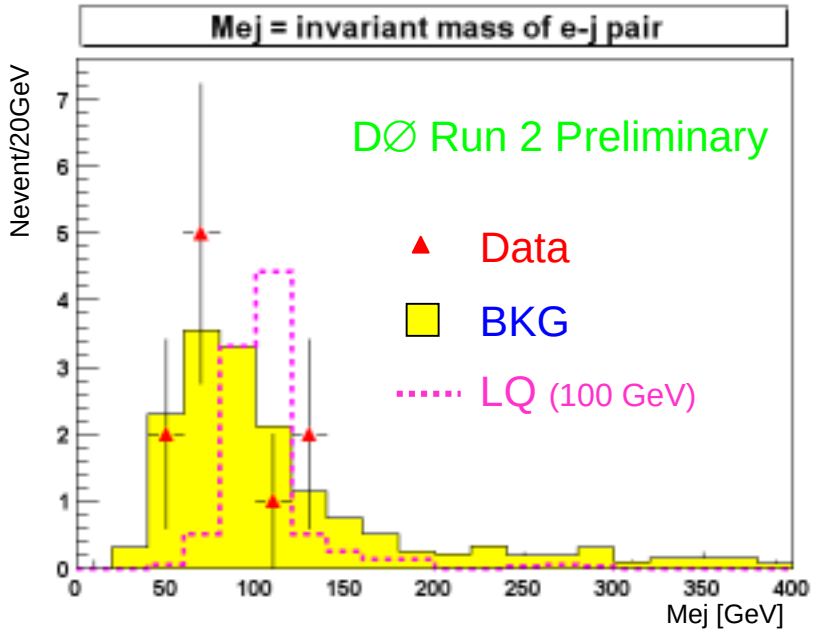


Clear Evidence of high impact parameter tracks in Muon Tagged sample!

New Phenomena: Leptoquark Search

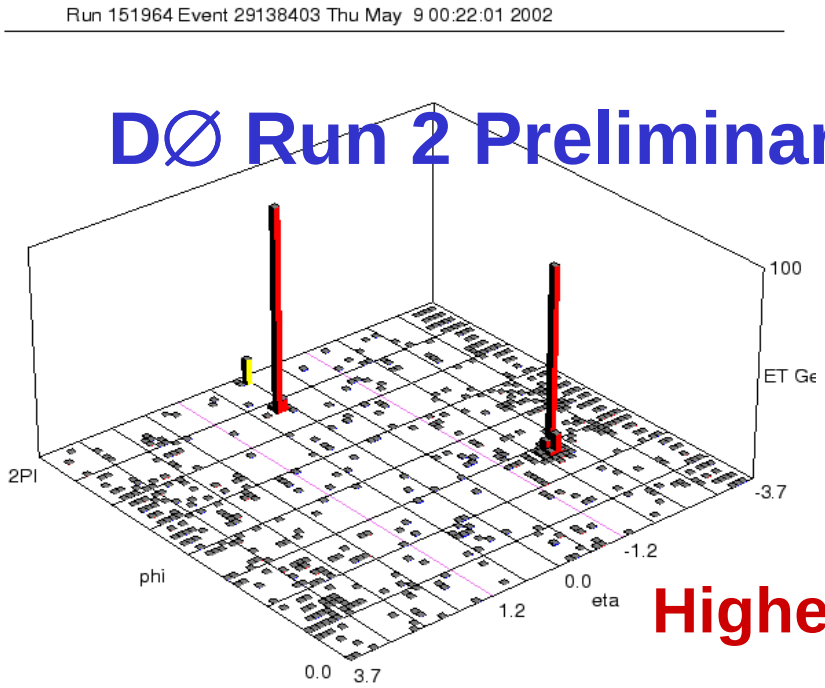
- **Compare data and background distributions**

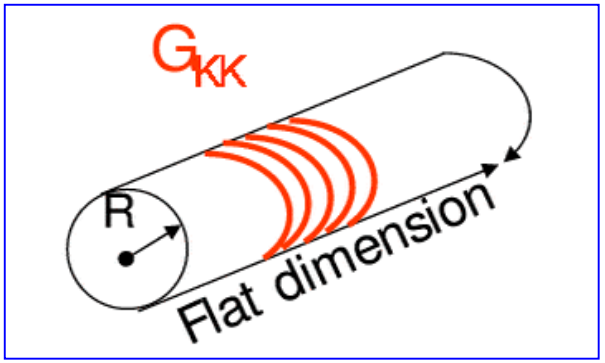




Data :	5 events
Total Background :	8.1 ± 4.0 events
• QCD :	7.8 ± 3.9 events
• Drell-Yan :	0.3 ± 0.1 events
LQ (m = 100 GeV) :	4.7 ± 0.6 events

Search For Extra Dimensions





»Looking for high mass di-EM pairs

»Sensitivity doubled wrt to Run 1.

Highest mass diEM candidate

EM1	EM2
E_T = 115.4 GeV η = 0.10 φ = 5.27 No track match	E_T = 109.7 GeV η = -2.10 φ = 2.19 No track match
M(diEM) = 376 GeV; cosθ* = 0.79; ME_T = 8.2 GeV	

What we can do with < 2 fb^{-1}

100pb^{-1}
*** measure first W, Z, jet, top, b, cross sections at 1.96 TeV**

300 pb^{-1}
*** pin down high-ET jet behavior (fix gluon PDF at large x)**
*** measure top mass with half current statistical error**
*** extra dimensions at a scale of 1.6 TeV**

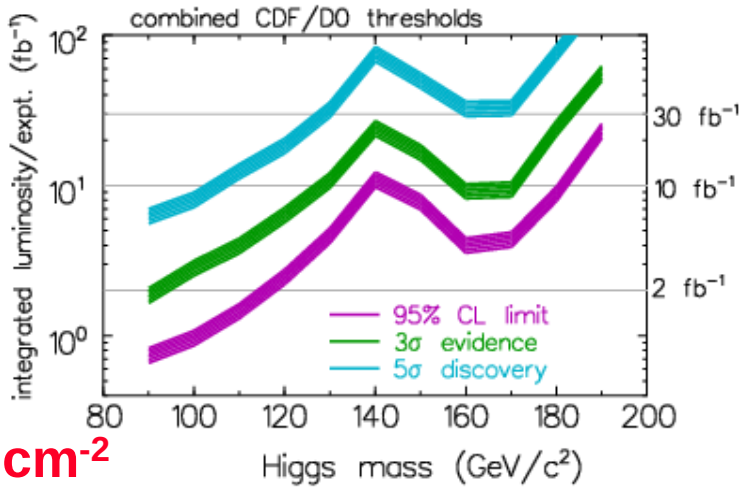
500 pb^{-1}
*** signals for WW, WZ production**
*** observe radiation zero in Wgamma process**
*** observation of single top quark production**

*** signals for technicolor?**

Interesting results will appear well before end of Run 2 a!

Run 2 b Upgrades

- **Present detector designed for ~ 2fb^{-1} and 2 × 10^{32} cm^{-2} s^{-1}**
- **Run 2 b goal: ~15 fb^{-1} before LHC physics**
  - **Physics motivation: Higgs and Supersymmetry**
  - **Exceeds radiation tolerance of existing silicon detector**
  - **Requires higher luminosities, ~ 5 × 10^{32} cm^{-2} s^{-1}, trigger upgrades**



Replace Silicon Detector with a more radiation-hard version

Improve impact-parameter resolution (b-tagging)

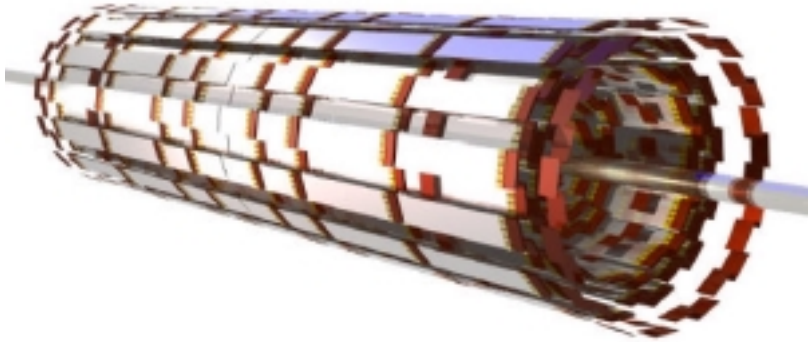
Maintain good pattern recognition Cover |η| < 2

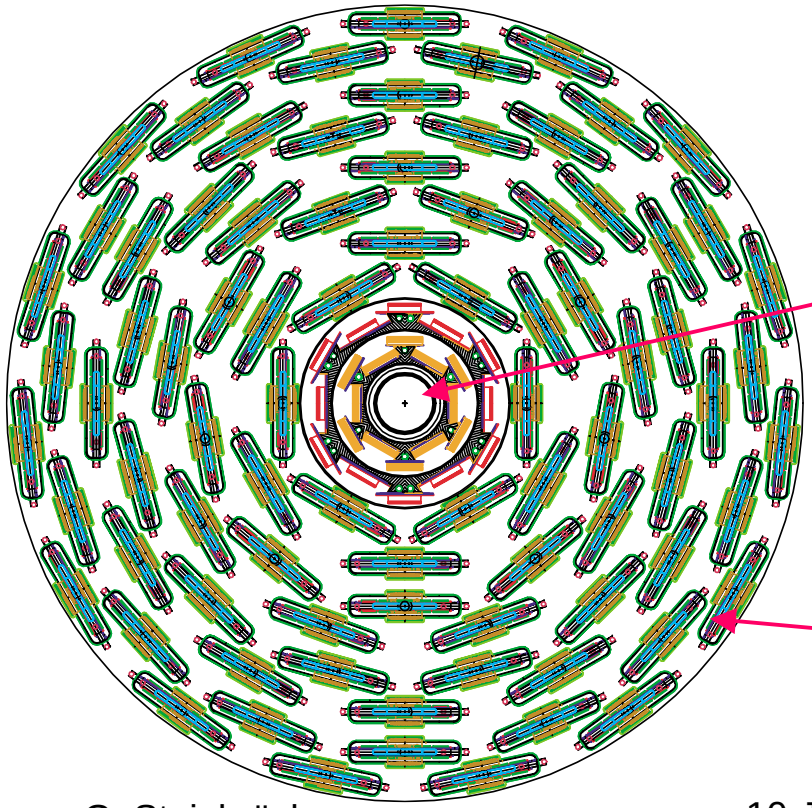
Upgrade Trigger

Shift functionality upstream and increase overall Level 1 trigger capability – contain rates, dead time

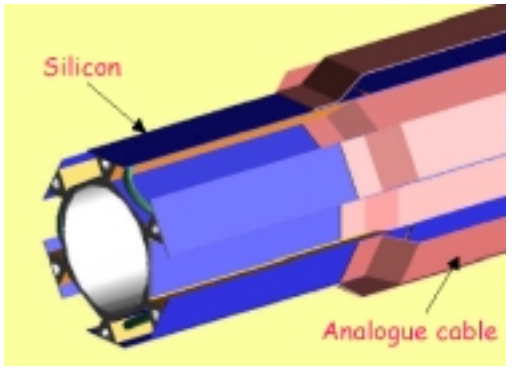
Incremental Upgrades to Level 2, Level 3 Triggers and online system

Silicon Detector Upgrade

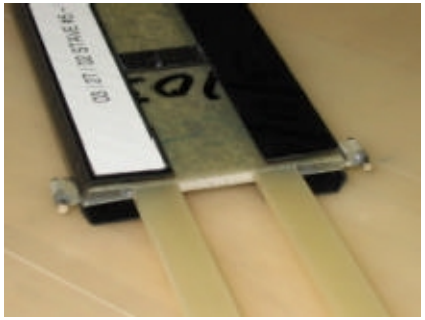




- **Single sided silicon, barrels only**
- **Detector installed in two halves inside collision hall in ~7 month shutdown**
- **Inner (vertexing) layers L0, L1**
  - **Axial only**
  - **mounted on carbon support**



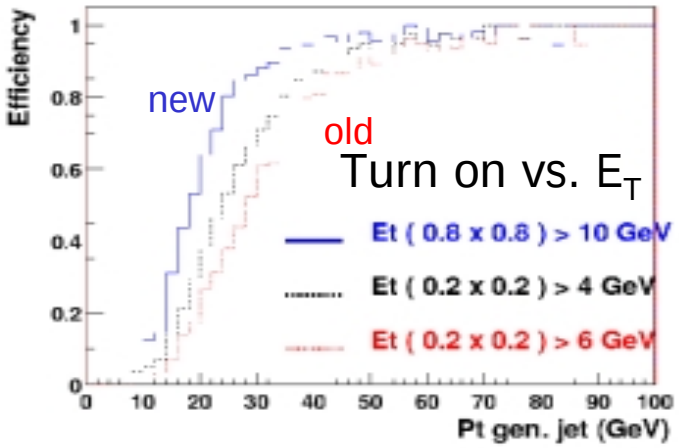
- **Outer (tracking) layers L2-L5**
  - **Axial and stereo (tilted sensors)**
  - **Stave structures**

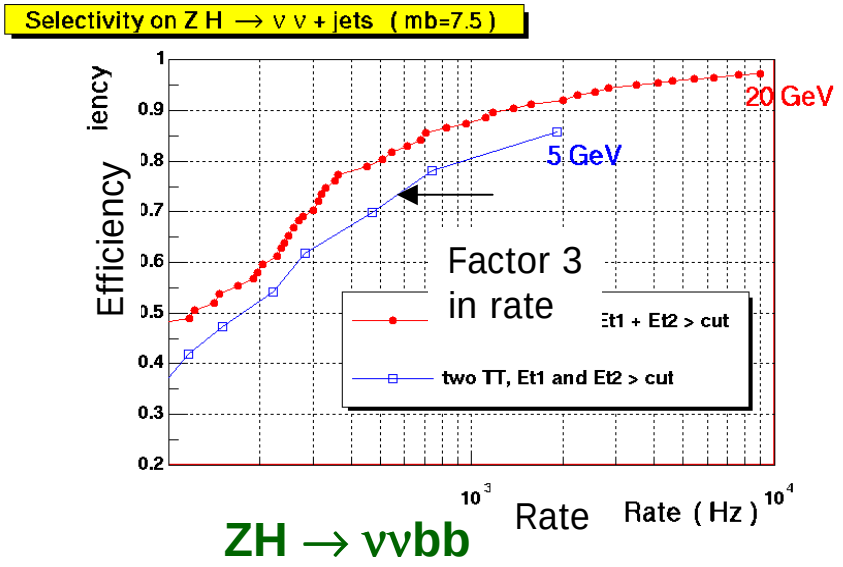


Trigger upgrades

System	Problems	Solutions
Cal	1) Slow signal rise ⇒ trigger on wrong crossing	• Digital Filter
	2) Trig on $\Delta\eta\times\Delta\phi$=0.2×0.2 TTs ⇒ poor resolution, slow turn-on	• Clustering (jets) • Isolation and shape cuts (e/γ)
Track	Rates sensitive to occupancy (i.e. number of min bias events)	• Narrower Track Roads • Improve Cal-Track Match

L1 calorimeter:





$ZH \rightarrow \nu\nu bb$

Conclusions

- First year of Tevatron Running was mainly used for commissioning the detector and the trigger system
- Meanwhile we have started to work on the RunII b upgrade.

- All subdetectors are operating well
- Software and Computing systems working well
  - keeping up with incoming data

- Now working on fine tuning of the detectors
- Level II Trigger commissioning under way
- L2 Silicon Track Trigger this fall
- Transition to Commodity L3 DAQ system done

- First results already presented at winter conferences
- First physics results coming soon!

- **Exciting years are ahead!**